POLLUTION PREVENTION AND MANAGEMENT STRATEGIES FOR MERCURY IN THE NEW YORK/NEW JERSEY HARBOR

May 14, 2002

by

Allison L. C. de Cerreño
Marta Panero
Susan Boehme

New York Academy of Sciences
New York, New York

Authors' Note

This is a truly multi-authored paper. Dr. Susan Boehme consolidated and integrated the scientific research provided by the various commissioned consultants and conducted her own research when necessary. Ms. Marta Panero provided all of the economic research and analysis as well the research on the mercury flows and pathways for products and sectors. Dr. Allison L. C. de Cerreño integrated the economic and scientific information, added the societal and policy contexts, and provided the overall logic and flow for the document.

Printed on Recycled Paper.

Report Available from:

New York Academy of Sciences
2 East 63rd Street
New York, NY 10021
www.nyas.org

Although the information in this document has been funded in part by US EPA under an assistance agreement to the New York Academy of Sciences, it has not gone through the Agency's publications review process and therefore, may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

FOREWARD

In 1997 the Academy was asked by the U.S. Environmental Protection Agency to explore the feasibility of using industrial ecology to study pollution in the New York-New Jersey Harbor. The Agency was concerned about pollutants that had, historically, been present in the harbor's sediment as well as those that were entering the harbor each year. Behind the specter of economic consequences were a number of questions amenable to scientific analyses: What is in the sediment? How much is there? Where does it come from? What happens to it once it gets in the harbor? What is the timeline of such processes? What can be done to prevent further pollution? The Academy, with its history of helping illuminate environmental issues by bringing the best of science to bear on analyses and solutions, accepted the challenge.

A workshop on the subject was convened at the Academy in the Fall of 1997. Scientific experts, regulators, people experienced in working on other harbors, and various public interest groups assembled in search of solutions to a broad set of Harbor concerns. A summary of the deliberations and conclusions of this workshop–endorsing the usefulness of an industrial ecological approach to analyzing the Harbor–was published by the Academy the following year. EPA then requested the Academy to undertake such a study; the Port Authority of New York and New Jersey, among others, agreed to co-sponsor the work. A key component of the project, the NY/NJ Harbor Consortium was launched in January 2000. Mercury was identified as the first pollutant for study. Aided by the advice of scientists familiar with mercury, the staff worked hard to analyze and synthesize the state of knowledge on mercury pollution in the harbor. The Consortium approved the study's findings and conclusions in December 2001. With this monograph, which reports the results of the mercury study, the Academy is pleased to publish the first detailed report from this important project. Reports on other aspects of this work, including four other pollutants, will reach you during the next phases of our work.

As Charles Powers describes in the Preface, one of the novel aspects of this project is the involvement and commitment of the people – from a variety of institutions and a wide range of backgrounds and experiences – who collectively comprised the Harbor Consortium. The Academy is grateful for their time and efforts in bringing the project to its current state. The Academy also acknowledges financial support provided to this project by the U.S. Environmental Protection Agency, Port Authority of New York and New Jersey, the Abby Mauzé Trust, The Commonwealth Fund, AT&T Foundation and J.P. Morgan. The Academy is also grateful to several staff members for their dedicated work and commitment to this project–Allison de Cerreño, Susan Boehme and Marta Panero. And finally, special thanks are also due to Charles Powers, who has so ably chaired the Consortium and provided excellent leadership.

Torsten N. Wiesel, M.D.
Chairman, Board of Governors

Rashid Shaikh, Ph.D.
Director of Programs

PREFACE

The reader will probably not have encountered any document quite like "Pollution Prevention and Management Strategies for Mercury in the New York/New Jersey Harbor." It is audacious in scope, rigorous in its scientific and analytic conclusions, and bold in its recommendations affecting a wide variety of institutional interests and practices. It does not pretend to solve all problems related to the flow of worrisome contaminants to this large and distinctive urban harbor. Still, together with the additional work now scheduled, we believe this project will provide a body of documents that should give us a comprehensive picture of what we, as a region, can do to protect these valuable surface waters.

This study parses the complex story of how mercury is transformed in water systems into a significant hazard that moves up the food chain to threaten both human beings and a wide variety of valued non-human receptors. It tells us how and from what sources and activities the contamination comes. It also shows what a diverse body of this region's citizenry–people who have become quite knowledgeable about the science of mercury pollution–has learned in more than two years of study. And it suggests the best ways to intercept some of this mercury before it causes harm. The formulation of these recommendations was aided by a survey that assessed the public's interest in the harbor and citizen willingness to help foster its health. This manuscript, then, is a call to specific action as well as a rare synthesis of evaluation and risk management.

Disciplines and approaches used to assess the threats posed by methyl mercury are, typically, not integrated as they have been in this document. Environmental measurement is itself reliably built only when, for example, the competencies of experts in exposure assessment, toxicology and biochemistry are in fruitful dialogue. Similarly, the regulatory regimes that promote pollution prevention are more effective if the tools of industrial ecology are used to analyze contaminant sources and, at the same time, develop related economic data about the costs associated with any risk management alternative considered. The findings of industrial ecology and environmental sciences are validated best when they are consciously woven together.

The authors of this document deserve commendation for their achievement. But those same authors would be the first to acknowledge that they are the beneficiaries of a highly unusual, likely unique, process that was imagined in 1997 by several people of vision and creatively hosted by the New York Academy of Sciences. It was a process that found an evolutionary home in a Consortium of committed stakeholders who fostered both debate and consensus around a body of data that became substantial because it was given the time and opportunity to mature into a sound scientific synthesis.

So what is the history? What were the threads that formed the fabric from which this document emerged? In 1997, a scientist from the Environmental Protection Agency persuaded his management that there was both need and opportunity to make the health of the harbor itself the "organizing principle of research." It was EPA's Region II Ocean Policy Coordinator, Joel O'Connor, who approached the New York Academy of Sciences with the idea of a workshop on "Industrial Ecology and the Environment: Applications to the New York Harbor." The Academy was rightly seen as a place where the integrity of scientific process would be well protected while the implications of those scientific findings were drawn.

In September 1997, I chaired the two-day workshop that O'Connor had proposed. The concept of a concerted effort to examine the sources and consequences of the flow of five major contaminants to the New York/New Jersey Harbor Watershed evolved. Industrial Ecology, just emerging as an interdisciplinary approach, would be part of the methodology. But there was concern that the sources needed to be related to the actual consequences–contaminants measured in the harbor and in living things in its waters. Still, it would not much matter if the scientists–even though deftly drawn from the region's agencies and universities–merely learned from where and how contamination occurs and issued a report. An extraordinary idea emerged from that workshop: the Academy should draw into and make integral to the scientific work a diverse body of citizens from a wide variety of institutions and sectors across the watershed. This would become the 30-plus member Harbor Consortium, an institution hosted and ably staffed by the Academy. The Consortium would become aware of other watershed analyses elsewhere in the world (specifically the Rhine Valley initiative in Europe and the Boston Harbor cleanup process). The Consortium would also work to find out, through both survey and active involvement with the region's communities and other study processes, how the people in the watershed viewed the harbor.

The central idea was that as the Academy drew many experts into the study of each pollutant, the Consortium would observe and comment on the process. It would become knowledgeable so as to be able to select each subsequent pollutant to be studied, evaluate the pollution prevention strategies, and seek to make consensus recommendations about which institutions or citizens need to alter their practices to protect the harbor. Through four general sessions, over a period of two years, the Consortium not only persisted, but it flourished–gathering increasing confidence in the quality of the science being developed and in its collective ability to make recommendations. We were lucky in that the first contaminant was mercury, a contaminant that's greatest threat occurs when mercury is literally "converted"–primarily by bacteria in aqueous environments–into methyl mercury. As the Consortium began focusing on methyl mercury, the regulatory spotlight shifted from elemental to methyl mercury. Since this work was occurring along with, and even as a part of, a changing scientific and regulatory focus, the Consortium found its work in defining how to intercept mercury a lively and engaging process.

The science was so interesting that as the assessment and the recommendations came together in December 2001, the Consortium responded with enthusiasm–and with an astute final bit of wisdom. "If we have learned how to connect the diverse sources of mercury to the way they may harm the harbor, and have worked back to what should be done to protect the harbor," the Consortium suggested by acclamation, "why should there be consensus only in the Consortium? Let's get the buy-in of the institutions that need to take additional steps to eliminate or intercept mercury in its path to the sea." The Consortium was improvising in uncharted waters. It sent its staff and leadership back to the sectors pinpointed as the mercury sources of primary concern to solicit support from those whose help was needed to reduce mercury contamination. In the intervening months, we have achieved extraordinary, involvement both regional and national of leaders in those affected sectors: producers, users, recyclers, etc.

Most participants clearly saw the logic of mercury reduction, proposed a series of innovative and more cost-effective ways of achieving sound results, and became real supporters of the Consortium report. Since the mitigation steps will cost, some sectors were, as expected, at best, sullen but they were not mutinous. Hence, this report has the full support of its Consortium and unexpected acceptance among those whose work to implement it is now beginning. Even during these last months, as the scientific issues became clear, there have been surprisingly coordinated efforts among those who must control and those whose actions will be needed to achieve major change in preventing mercury pollution of the harbor.

As chair of this Consortium, I have had an opportunity to work with the many talented people named throughout this report–in its acknowledgements, in the very many places where specific contributions are cited, and in the naming of functions, task forces and members of this complex process. Kathy Callahan (US Environmental Protection Agency) and Thomas Wakeman (The Port Authority of New York/New Jersey) have provided valuable leadership representing not only their organizations but also the broader array of concerns that federal and state agencies are faced with. The authors–Allison de Cerreño, Marta Panero and Susan Boehme–have been colleagues as well as talented staff. The work condensed here has had to proceed in the midst of the incredible impacts of the events of September 11 and significant changes at the Academy as well. From it all emerges not merely a document, but the basis for a new practice–a benchmark if you will–for how this kind of science can be done very well. Indeed, it demonstrates that when a social concern is the organizing principle for research, the public can be invited in to observe as the hypotheses are tested, so that they are fully prepared to advocate a set of responsible inferences for action and, thereby, attract the real interest and often the support of those who must act to protect resources we all know are valuable. And keep tuned. We are poised to do this again and again for other contaminants that threaten this important New York/New Jersey Harbor.

Charles W. Powers
Consortium Chair

MEMBERS OF THE NEW YORK/NEW JERSEY HARBOR CONSORTIUM

Charles Powers, *Principal Investigator, Consortium on Risk Evaluation with Stakeholder Participation (CRESP-DOE), and Professor of Environmental and Community Medicine UMDNJ-RWJMS*

George Rupp, *President, Columbia University*

Members

Winifred Armstrong, *Economist, Regional Plan Association*

Brad Allenby, *Vice-President, Environment AT&T Co.*

Mary Buzby, *Principal Scientist, Merck & Co.*

Phyllis Cahn, *Associate Director, Aquatic Research and Environmental Assessment Center (AREAC), Brooklyn College, CUNY*

Carter Craft, *Director of Programs, Metropolitan Waterfront Alliance*

Paul J. Elston, *Chairman, NY League of Conservation Voters*

Herzl Eisenstadt, *Counsel to the International Longshoremen's Association*

Eric Erdheim, *Senior Manager Government Affairs, National Electrical Manufacturers Association*

Roland A. Ericsson, *Marine Engineer, Environmental Business Association of New Jersey and Golder Associates*

Leonard Formato, Jr., *President, Boulder Resources*

Russell Furnari, *Environmental Strategy and Policy, PSEG Services Corporation*

Frederick Grassle, *Director, Institute of Marine and Coastal Sciences, Rutgers, the State University of New Jersey*

Manna Jo Green, *Environmental Director, Hudson River Sloop Clearwater*

Bryan Jantzen, *President, Full Circle Inc.*

Jim Hall, *Superintendent, Palisades Interstate Park Commission*

Philip Heckler, *Deputy Director, Environmental Affairs, New York City Department of Environmental Protection*

Ronald G. Hellman, *Director, Americas Center on Science & Society, the Graduate School and University Center of the City University of New York*

Colleen Keegan, *Project Director, NYC Hospitals Project, Health Care Without Harm, Mount Sinai School of Medicine*

Zoe Kelman, *Scientist, New Jersey Department of Environmental Protection*

Keith Lashway, *Director, Environmental Management Investment Group, Empire State Development Co.*

Simon Litten, *Research Scientist, Division of Water, NYS Department of Environmental Conservation*

Thomas Morris, *Program Director, IBM Corporation*

Wendy Neu, *Chairman and CEO / Vice President, Environmental & Public Affairs, Hugo Neu Co.*

Frank Oliveri, *Deputy Director, Collection Facilities, NYC Department of Environmental Protection*

Randolph Price, *Vice President of Enironment, Health & Safety, Consolidated Edison Co.*

Stephen D. Ramsey, *Vice-President, Corporate Environment Programs, General Electric Co.*

Ira Rubenstein, *Executive Director, Environmental Business Association of New York*

Anthony Rumore, *President, Joint Council 16, International Brotherhood of Teamsters*

Manuel Russ, *Member, Citizens Advisory Committee to NYC Department of Environmental Protection*

Martin P. Schreibman, *Director, Aquatic Research and Environmental Assessment Center (AREAC), Brooklyn College, CUNY*

Nancy Steinberg, *Research Project Associate, Hudson River Foundation*

Dennis Suszkowski, *Science Director, Hudson River Foundation*

John T. Tanacredi, *Chief, Division of Natural Resources, U.S. Department of the Interior*

National Park Service, Gateway National Recreation Area

Nickolas Themelis, *Professor, Earth Engineering Center, Columbia University*

Andrew Voros, *Executive Director, NY/NJ Clean Ocean & Shore Trust*

Mary Werner, *Director, Pollution Prevention Unit, NYS DEC*

Rae Zimmerman, *Director, Institute for Civil Infrastructure Systems, Wagner Graduate School of Public Service, New York University*

Ex Officio Members

Annette Barry-Smith, *Project Manager, Port Commerce Department, Port Authority of NY & NJ*

Kathleen Callahan, *Division Director, U.S. EPA- Region 2*

Steve Dorrler, *Scientist, Port Authority of NY & NJ*

Richard Larrabee, *Director, Port Commerce Department, Port Authority of NY & NJ*

Irene Y. Purdy, *Program Manager, EPA Region 2*

Walter Schoepf, *Environmental Scientist, US EPA Region 2*

Thomas Wakeman, *General Manager, Waterways Development, Port Authority of NY & NJ*

HARBOR CONSORTIUM ACTION GROUPS

Mercury

Joanna Burger, *Professor, Division of Life Sciences, Environmental & Occupational Health Sciences Institute, Rutgers University*

William Fitzgerald, *Professor, Department of Marine Sciences, University of Connecticut*

Dr. Michael Gochfeld, *Professor, Environmental and Occupational Health Sciences Institute, Robert Wood Johnson Medical School, Rutgers University*

Joel S. O'Connor, *Adjunct Associate Professor, SUNY at Stony Brook, Retired EPA Administrator*

Valerie Thomas, *Research Scientist, Center for Energy and Environmental Studies, Princeton University*

Mercury Methylation

Michael Aucott, *Research Scientist, Division of Science, Research and Technology, New Jersey Department of Environmental Protection*

Nada Marie Assaff-Anid, *Department Chair and Associate Professor, Chemical Engineering Department, Manhattan College*

Janine Benoit, *Geosciences Department, Princeton University*

Michael Connor, *Vice President for Programs and Exhibits, New England Aquarium*

Charles Driscoll, *Distinguished Professor of Civil and Environmental Engineering, Syracuse University*

William Fitzgerald, *Professor, Department of Marine Sciences, University of Connecticut*

Carlton Hunt, *Research Leader, Battelle Ocean Sciences Inc.*

Robert P. Mason, *Assistant Professor, (UMCES) Chesapeake Biological Laboratory,Center for Environmental Sciences, University System of Maryland*

Joel S. O'Connor, *Adjunct Associate Professor, SUNY at Stony Brook, Retired EPA Administrator*

TABLE OF CONTENTS

GUIDE TO TABLES, CHARTS, AND FIGURES

GLOSSARY OF TERMS

EAF	electric arc furnace
EPA	Environmental Protection Agency
ESCO	Energy Service Company
Hg	mercury
IE	industrial ecology
MACT	maximum available control technology
MeHg	methylmercury
MWC	municipal waste combustion
MWI	municipal waste incineration
NEMA	National Electrical Manufacturers Association
NEWMOA	Northeast Waste Management Officials' Association
NJ DEP	New Jersey Department of Environmental Protection
NYAS	New York Academy of Sciences
NYC DEP	New York City Department of Environmental Protection
NYS DEC	New York State Department of Environmental Conservation
P2	pollution prevention
PAC	powdered activated carbon injection
POTW	publicly owned treatment works facilities
TRC	Thermostat Recycling Corporation
WWTP	wastewater treatment plant

ACKNOWLEDGMENTS

The New York Academy of Sciences and the authors acknowledge the assistance of the many people who provided information, data, references, and analysis toward the completion of this report. We are particularly grateful for the research performed for the Academy by William Fitzgerald, Joel O'Connor, Julio Huato, Nickolas Themelis, Alexander Gregory, and Janina Benoit, which formed the basis for much of the data in this document. We also thank the team at the Marist College Institute of Public Opinion, including especially Barbara Carvalho, Lee Miringoff, and Kathleen Tobin-Flusser, for the development, implementation, and analysis of the public opinion survey, and Bryan Williams for his additional assessments.

We especially acknowledge the assistance of Michael Aucott (NJ DEP) and the New Jersey Mercury Task Force. Peter Berglund (Metropolitan Council, St. Paul, MN), Gregory Camacho (NY Presbyterian), Tom Corbett (NYS DEC), John Gilkeson (MN Pollution Control Agency), Brian Jantzen (Full Circle Recycling), Philip Heckler (NYC DEP), Zoe Kelman (NJ DEP), Simon Litten (NYS DEC), and Tim Tuominen (WLSSD) were all extremely helpful in providing key data at various stages. Also, a special thanks to John Erickson and Audra Nowosielsky, who provided access to key databases at RPI.

The Academy and the authors thank the Consortium members for their time, energy, and assistance during each step of the process. They were untiring in their willingness to talk to us when we had questions. We especially thank the Chair of the Consortium, Charles Powers, for his guidance from beginning to end, in thinking about the key components necessary for the document as well as the flow of argument. Also, we thank the Academy's Board of Governors for welcoming this unusual initiative by the Academy to serve its home region and Rodney Nichols, for his indefatigable support and encouragement. Special thanks to Rashid Shaikh for his efforts to ensure the successful completion of this report and the continuation of the project.

Many informative discussions were held with the following people from within the region and from other parts of the country. The Academy thanks Deborah Augustin (New Hampshire Hospital Assoc.), Lawrence Bailey (NY County Dental Society), Carol Beal (Monroe County Department of Health), Charles Bering (MWRA), Martha Bell (Association for Energy Affordability), Owen Boyd (SolmeteX Co.), Janet Brown (Beth Israel Hospital), Jennifer Buchanan (NYC Health & Hospital Co.), Joanna Burger (Rutgers), Gregory Dana (Alliance of Automobile Manufacturers), Joe Day (Air Cycle Co.), Grace Garcia (NYS Div. of Consumer Affairs), Jeff Gearhart (Ecology Center), Thomas Gentile (NYS DEC), Bill Gleason (American Re-Fuel Co. of NY), Javad Ghaffario (Palo Alto Sanitary District), Michael Giamott (S&G Medical Waste Incineration Facility), Teri Goldberg (NEWMOA), Kathy Gran (Daimler-Chrysler), Jamie Harvie (Institute for a Sustainable Future), Chris Herb (Clean Harbors Recycling Services), James Heckman (NC P2 Div.), Fran Hoffman, Jim Hogan (Westchester Solid Waste Div.), Nelli Kraytsberg (Woodhull Medical Center), Kathy Kromer (Association of Home Appliance Manufacturers), Roland Lochan (NYC DEP), Robert Madarozzo (Wheelabrator), Richard Malaccynski (NYS DEC), Rebecca Maran (American Hospital Assoc.), Robert Miller (Auto Recyclers Association of New York State), Mary Moskal (NJ Dental Association), Wendy Neu (Hugo Neu Co.), Jerry Odenwelder (Bethlehem Apparatus, Inc.), Fotinos Panagakos (UMDNJ), Mario Parissie (Sprout Brook Landfill), Chris Pettinato (Columbia University School of Dental & Oral Surgery), John Reindl (Dane County Mercury Reduction Plan), A.J. Shroft (NYS DEC), Ana Smith (Daimler-Chrysler), Ron Stanard (NYS DEC), Marvin Stillman (Strong Memorial Medical Center), Marc Sussman (Dental Recycling North America), Burt Tosser (NYS DEC), Derek Veenhof (American Re-Fuel Co. of NY), Paul Walitsky (Philips Lighting Co.), Mary Werner (NYS DEC), Suzanne Winicker (Cornell Veterinary Library), and Allen Woddard (NYS DEC).

Numerous people at EPA Region 2 contributed data, referrals, and reviews, including Irene Purdy, Walter Schoepf, and Carl Plossl, and also Seth Ausubel, Darvene Adams, Diane Buxbaum, Deborah Freeman, Tristan Gillespie, Lorraine Graves, and Deborah Meyer. Several members from other divisions of EPA also helped greatly, including Alexis Cain of Region 5, and Ellen Brown and Bill Maxwell from EPA Headquarters. The participation of Thomas Wakeman, Annette Barry-Smith, and Steven Dorrler from the Port Authority of New York and New Jersey was especially helpful during discussions of the public opinion survey and pollution prevention.

Finally, the Academy acknowledges the following funders for their contributions to this effort: The AT&T Foundation, The Commonwealth Fund, JP Morgan, the Abby R. Mauzé Charitable Trust, the Port Authority of NY & NJ, and U.S. EPA Region 2. Without their financial support, this project would not have been possible.

EXECUTIVE SUMMARY

Under the auspices of the New York Academy of Sciences, the Harbor Consortium was charged with the task of recommending pollution prevention (P2) and management priorities and strategies for mercury in the New York/New Jersey Harbor. To assist in the fulfillment of this task, the New York Academy of Sciences gathered the relevant scientific, economic, and public policy information to provide the context for this decision-making process. This document summarizes that research, suggests a prioritization of efforts based on the scientific data, provides a set of potential P2 recommendations and strategies to achieve them, and identifies the key stakeholders who will need to share responsibility for implementation.

The Focus of the Research and Recommendations

The primary geographical focus of this document is the New York/New Jersey Harbor. Decisions regarding research, the setting of priorities, the development of recommendations and strategies are always weighed against the likelihood that a given source of mercury will have a direct or indirect effect on the Harbor. Thus, in the following pages there are various references to the Harbor's Watershed, which extends north toward Albany and west along the Mohawk River toward Utica, and includes much of northern New Jersey. For the purposes of this document, however, mercury being released or deposited in the Watershed is tracked only if there is a chance of it making its way to the Harbor. This is not to say that there are not locations which have critical local problems associated with mercury that need further study and/or action, only that they are not the focus of this particular body of research.

The primary objective of this body of research is to develop P2 recommendations and management priorities and strategies that will allow for an ecologically healthy Harbor while maintaining its economic viability. This is not therefore a document that deals in great detail with the negative health effects of mercury on individuals. It does, however, take into consideration the importance of methylmercury as the most toxic form of mercury for humans and biota. Thus, in addition to weighing priorities against the likelihood that a given source of mercury will have an effect on the Harbor, they are also weighed against the prospects for methylation.

Prioritizing an Agenda

Mercury arrives in the Harbor via three routes: air, solid waste, and wastewater. Against the backdrop described above, the Consortium recommends focusing on wastewater as the most direct source of mercury and most significant source of methylmercury to the Harbor. Prioritizing wastewater is based on scientific research that demonstrates this is the largest source of mercury to the Harbor and that there are probable higher methylation rates associated with wastewater in effluents. The three major sectors contributing mercury to wastewater effluent are dental facilities, hospitals, and laboratories. Thus, P2 strategies for these sectors are the most significant leverage points for wastewater.

A second priority, and still critical to reducing mercury contributions to the Harbor, is atmospheric inputs. These emissions result from incineration of mercury-bearing products and combustion of fuels that contain trace amounts of mercury, as well as through volatilization. About one-third of the mercury released locally to the airshed is deposited on the Watershed and is available to be washed into the rivers and streams, thereby making its way to the Harbor. There is also an extra-regional input, mainly from coal combustion in the Midwest, though there are inputs from global emissions also. Thus, the solutions to atmospheric inputs extend beyond the Watershed. Nevertheless, there are local, practical solutions for some of these inputs.

Finally, the inputs of mercury to landfills/monofills from solid waste compose the largest set of mercury transfers. However, because tentative estimates suggest that this mercury is sequestered, and therefore poses a lower direct risk to the Harbor (at least for some length of time), this pool has been accorded the lowest priority despite its large size. Addressing wastewater mercury inputs has the added benefit of decreasing landfill/monofill inputs by greater than 60% because the three critical sectors (dental, hospital, laboratory) are major contributors to this pool as well. Furthermore, P2 recommendations are provided for several key products that contribute to mercury to landfills and monofills because the technology (and in some cases, the needed infrastructure) is already available to recycle/collect these items.

Poorly characterized and potentially large sources of mercury in the Harbor include the Superfund sites, brownfields, and uncontrolled landfills in the Watershed, particularly along the western side of the Harbor. Historically, mercury usage in this area was extensive. However, there are no estimates of how much of this mercury is entering the Harbor and very little data on how much mercury is in the soils and groundwater at these sites. Therefore, given the potential loadings from these sources these sites should be targeted for future studies to determine whether they need to be factored in to mercury P2 plans for the Harbor, but the Consortium felt it unwise to wait for the completion of such studies to put forth the current recommendations.

Recommendations of the Consortium

The recommendations are divided into three types: recommended priorities for action, recommended priorities for research, and pollution prevention and management recommendations for each key product and sector. Although how the Consortium arrived at each of these recommendations is described in the document, the full set of recommendations is detailed below.*

Priorities for Action:

- Decrease mercury discharges from wastewater
- Decrease atmospheric inputs of mercury
- Decrease inputs of mercury to landfills and monofills

Priorities for Research:

- Develop data related to contaminated land-based sites in the watershed
- Link initial findings on dredged materials to future contaminant studies

P2 and Management Recommendations for Products and Sectors:

Discharges from Wastewater

Dental Sector

Implement a tiered approach that

- Institutes filtration, collection, and recycling in the short term; and,
- Moves toward substitution of amalgams by safe, durable, and cost-effective alternatives in the long term

Hospitals

- Substitute non-mercury alternatives for mercury-containing products
- Prevent breakage of current mercury-containing products

Laboratories

- Substitute non-mercury alternatives for mercury-containing products
- Prevent mercury discharges to sewers

Atmospheric Inputs

Vehicle and Appliance Switches

- Recycle/retire mercury switches already present in automobiles, light trucks, and appliances
- Develop safe, non-mercury alternatives for switches utilized in gas pilot-light ranges
- Develop an understanding of the uses of mercury switches in heavy-duty trucks and buses, the amount of mercury present, and the availability and cost-effectiveness of non-mercury alternatives

Fluorescent Lamps

- Comprehensive recycling
- Develop more effective management technologies

Furnaces

- Reduce emissions
- Substitute non-mercury-containing fuels

Inputs to Landfills and Monofills

Mercury-Switch Thermostats

- Increase the rate of recycling
- Promote purchase and proper use of energy star programmable thermostats

Household Thermometers

- Substitute non-mercury alternatives
- Increase the rate of retiring mercury-containing models

What, How, and Who

The above recommendations describe what needs to be done and are based on the scientific research, coupled with the economic analyses, and an understanding of political and societal constraints. Equally important to answer are how to accomplish these goals (strategies) and who should bear the responsibility. Thus, as the recommendations for pollution prevention and management are made throughout the document, they are coupled with specific strategies

* Although religious and cultural uses of mercury are discussed at various points throughout the document, no recommendations for this potential source are being made at this time. Although there are a few studies that point to the individual hazards of such practices, the extent of such practices and how much of the mercury utilized actually makes its way into the Harbor are unclear. Furthermore, for the figures that do exist, there are very large error bars associated with them. Thus, it is felt that sufficient evidence is lacking to make a recommendation that singles out a particular ethnic or cultural group.

for achieving them. These strategies are, in many cases, based on best practices from other locations around the nation. In some cases, there are multiple strategies listed. These are rarely exclusive of each other, and often more than one can be implemented at a time; they are purposely not prioritized because each locale and/or industry needs to determine which strategies will best help it achieve the desired results. Finally, in each case there is a list of the key stakeholders who need to help implement the strategies to achieve the recommendations. This was not an exercise in finger-pointing. The Consortium recognizes that pollution prevention is a joint effort, and that success is best achieved when different sectors with varied interests find ways to work collaboratively toward a common goal. Consortium members appeal to the various stakeholders described in the following pages to work together in a genuinely cooperative manner.

1. INTRODUCTION

The goal of the New York Academy of Sciences project "Industrial Ecology, Pollution Prevention and the NY/NJ Harbor," is to identify pollution prevention (P2)[1] strategies for several key contaminants affecting the Harbor. At the center of the project is a Consortium of stakeholders[2] who guide the research and assess the results. Utilizing an industrial ecology framework, coupled with economic assessments, and informed by a recently conducted public opinion survey, the Consortium seeks to develop P2 recommendations that are scientifically sound, economically feasible, and acceptable to residents and businesses in this region.[3]

1.1. Why Mercury?

The first contaminant chosen for study by the Harbor Consortium was mercury.[4] Mercury is a widespread element that enters the environment through natural and anthropogenic processes. It is found on land and in the earth's crust, in the air, and in water. There are three forms of mercury: elemental, inorganic, and organic compounds. Once in the environment, regardless of initial source, both inorganic and organic mercury compounds may be transformed through a variety of natural or human-made processes.[5]

Under a specific set of conditions that includes the presence of sulfate-reducing bacteria, low sulfide levels, an anoxic environment, and the presence of organic matter, inorganic mercury can be converted to methylmercury (MeHg), the form of most concern for humans and wildlife. This occurs predominantly in the sediments and sludge of aquatic systems, but can also occur in the water itself. Both inorganic mercury and methylmercury may enter the food chain, but only the latter bioaccumulates and biomagnifies, thus making MeHg of particular concern for those organisms, including humans, at the upper levels of the food chain, who are exposed predominantly through the ingestion of mercury-contaminated fish.

Once exposed to certain forms of mercury through the lungs, gastrointestinal tract, or skin, the human body has few means to eliminate it. Moreover, mercury is known to cross the placenta and has been found in maternal milk. Exposure to different species of mercury produces different toxicological effects. Inorganic mercury salts and mercury vapor, for example, have a greater negative effect on the kidneys than other mercury species, whereas organic mercury compounds have a greater tendency to directly affect the brain. Among the toxicological effects of exposure to mercury vapor (elemental) are acute bronchitis and tremors. Prolonged exposure can lead to serious and irreversible neurological damage, including loss of memory and changes in behavior, as well as to increased salivation and gingivitis (gum disease). Negative effects of exposure to methylmercury are primarily neurotoxic and may include tingling sensation around the extremities, ataxia, fatigue, vision and hearing loss, tremor, and potentially coma and death.[6]

1.2. The Current Regulatory Environment

The toxic effects of mercury on humans, as well as on the environment, and especially on fish and other wildlife, have long been acknowledged. By the 1960s, realizing that the major source of mercury for humans was through the consumption of mercury-contaminated fish, the Food and Drug Administration moved to establish an action level of 0.5 ppm MeHg for fish being marketed for food (1969). This threshold actually was increased by the FDA to 1.0 ppm MeHg in 1979. The EPA also established advisories for live fish and for water, both of which have been continuously updated over the years.[7]

Individual states are responsible for tracking fish and

1. For the purposes of this study, pollution prevention includes all approaches that potentially decrease the amount of mercury entering the Harbor, including approaches such as recycling and reclamation. This is somewhat different from the EPA definition of P2 as solely source reduction. Whereas source reduction is the ultimate goal, this Agency definition limits possible interim approaches that would decrease inputs of mercury to the Harbor. For a more complete description of the range of P2 definitions, see Center for Sustainable Systems, "Pollution Prevention as Defined under the Pollution Prevention Act of 1990," at http://www.umich.edu/~nppcpub/p2defined.html.
2. The Harbor project Consortium includes representatives from government, industry, academia, labor unions, environmental groups, and watershed citizens. It is the Consortium that made the final P2 recommendations for mercury in the NY/NJ Harbor.
3. The Academy project began in Fall 1998 with the signing of a Cooperative Agreement with U.S. EPA Region 2. The work that forms the basis for this paper and its recommendations, including the scientific and economic research, as well as the public opinion survey, has been funded through the project by The Commonwealth Fund; JP Morgan; the Abby Mauzé Charitable Trust; the Port Authority of NY & NJ; and U.S. EPA Region 2.
4. In addition to mercury, the Consortium has also chosen to study cadmium, PCBs, and dioxins. A decision on the final contaminant of study is pending.
5. Throughout the paper, when the term mercury is used, and no form is specified, it refers to total mercury.
6. Curtis D. Klaassen, ed., *Casarett and Doull's Toxicology: The Basic Science of Poisons,* 5th edition (NY: McGraw-Hill, 1996), pp. 709-712. For more on the toxicology of methylmercury, see National Research Council, *Toxicological Effects of Methylmercury* (Washington, DC: National Academy Press, 2000).
7. See U.S. EPA's Office of Water website at www.epa.gov/ost. Individual state advisories are also updated regularly. To review the most current advisories for New Jersey and New York, see www.nj.gov/dep/dsr/njmainfish.htm and http://www.health.state.ny.us/nysdoh/environ/fish.htm, respectively.

wildlife in lakes, rivers and streams. Using their own standards, each state then issues advisories, bans, and warnings on fishing and fish consumption and establishes its own criteria for water quality standards. New York State has adopted a water quality standard of 0.7 ng/L dissolved for saltwater for the protection of human health from the consumption of mercury-contaminated fish. New Jersey has adopted the EPA freshwater and estuarine surface water criterion of 0.3 µg/g methylmercury in fish tissue but is considering revising these guidelines to protect fish and wildlife.[8]

As scientific understanding of mercury's toxicological effects increased and new technologies for studying mercury, and especially methylmercury, became available, no longer were the thresholds established in past decades sufficient. Thus, in December 2000 the U.S. EPA not only recommended a new threshold concentration, but also refocused its own measurement on methylmercury in live fish (at 0.3 ppm) rather than on overall mercury levels.[9] The FDA continues to be under pressure to revise its threshold levels as well.

During this same period, there were increased calls around the nation for a ban on mercury and/or mercury-containing products. In 1990, a ban on the use of mercury in paints and pigments entered into effect, and between 1989 and 1992, new technologies were phased in to reduce the use of mercury in battery production.[10] Estimates of industrial use of mercury in the New York/New Jersey (NY/NJ) Harbor Watershed indicate a steep decrease over the past 20 years, related to the bans and new technologies and to broad decreases in industrial activity in the region, and increases in recycling of mercury-containing products. This decrease is reflected in measurements of the water, sediments, and possibly in organisms from the Harbor. Despite these decreases in mercury inputs to the Harbor, however, numerous pathways remain, and mercury still poses a threat to wildlife and fish and remains a potential threat to humans in the region.

1.3. Some Methodological Notes

While recognizing that mercury pollution is a nationwide (and, indeed a global) concern, the New York Academy of Sciences' project and the NY/NJ Harbor Consortium focus on preventing pollution to a specific water body, namely, the NY/NJ Harbor. Thus, when examining all flows of mercury, the question is always asked: "What is the likelihood that this pathway leads to the Harbor, either directly or indirectly?" Furthermore, because methylmercury is of most concern, a second question is asked: "What is the likelihood that this particular flow of mercury will result in the conversion of mercury to methylmercury?" It is against these questions that priorities are set.

Mercury has been entering the NY/NJ Harbor for centuries and is found throughout Harbor sediments and the soils of the Watershed. Despite significant declines of mercury inputs to the Harbor during the last three decades, cycling of this already-present mercury continues, with mercury moving between sediments and soils, the water column, and biota under various conditions. Nevertheless, although some discussion is provided regarding this cycling of mercury,[11] fully establishing its impact on the Harbor is beyond the scope of this report. With a goal of developing pollution prevention plans, this study focuses on new sources of mercury to the Harbor in an effort to reduce mercury inputs further.

Throughout the study, the determination of releases of mercury and distribution between air, water, and solid waste are based on regional estimates when the data exist. Where possible, these data are compared with national estimates. Because it is assumed that regional estimates are more accurate, they are also used (when available) to determine initial and final distributions and costs. As is true for all studies of mercury flows, these estimates can have large errors associated with them. In some cases, it is difficult to quantify those errors.

Because there are often multiple points for pollution prevention measures, whenever possible data are presented in kilograms of mercury per year (kg/yr), and costs are described as dollars per kilogram of mercury per year. Thus, comparisons may be drawn and decisions resulting in pollution prevention measures that are scientifically sound as well as economically, socially, and politically feasible can be made more easily.

8. NJ Mercury Task Force, *Executive Summary & Recommendations,* http://www.state.nj.us/dep/dsr/mercury_task_force.htm.

9. The relationship between the concentration of mercury in water and sediments and its conversion to methylmercury is still not fully understood. Thus, no effects range low (ERL) or effects range medium (ERM) for methylmercury in water has been established by regulatory agencies at this time.

10. U.S. EPA, Office of Air and Radiation, *Mercury Study Report to Congress,* v. 8 (Washington, DC: U.S. EPA, Dec. 1997), EPA-452/R-97-003. The new technologies for battery production resulted in a 94% decrease in the amount of mercury contained in batteries. Also, for more on mercury in paints, see http://www.orcbs.msu.edu/AWARE/pamphlets/hazwaste/mercuryfacts.html.

11. See Section 2.3, "Gaps in Our Knowledge" for a short discussion of the mass balance calculations of Fitzgerald and O'Connor.

2. INDUSTRIAL AND ECOLOGICAL PATHWAYS

To assist the Academy in gathering the relevant data, the Consortium's Mercury Action Group[12] was organized under the auspices of the New York Academy of Sciences. Several mass balance/releases studies (including data from the New Jersey Mercury Task Force which finalized its report in April/May 2002) were identified and presented to the group. The importance of the different species of mercury, and especially methylmercury also was discussed, and members of the Action Group determined that a better quantification of methylmercury in the Harbor was needed to address the most toxic effects of mercury in the Harbor. The analyses from the Mercury and Methylmercury Action Groups form the basis for the recommendations discussed in the following pages.[13]

2.1. Industrial Ecology as an Approach to Assessing the Flows of Mercury in the NY/NJ Harbor

An industrial ecology (IE) approach is utilized to identify the sources and quantify the amount of mercury entering the Harbor. IE is a system-based approach through which economic systems and environmental systems are studied in concert. This methodology helps understand how and from where contaminants enter the Watershed and airshed and identifies the most effective levers to reduce or eliminate the contamination.

IE is especially helpful in discerning the key levers for preventing new mercury inputs, because mercury entering the Harbor typically passes through several pathways or pools before release, reuse, or sequestration that are not easily identified without a systems view. Thus, IE enables one not only to identify where mercury enters the Watershed, but also to track its pathway from production and usage through its release, disposal, recycling, or export.[14] The information derived from this analysis is then used to make informed recommendations for P2 strategies.

The first step toward defining an industrial ecological view of mercury in the Harbor is to identify the major sources, sinks, and flows of mercury within the Harbor Watershed by determining a mass balance for mercury including both intra- and extra-regional mercury sources.[15] Then, individual sectors, products and processes that use and/or release mercury to the environment must be identified and quantified, with attention paid to how the releases to air, water (wastewater), and solid waste (landfills) are distributed.[16] Where possible, comparisons are made between the estimates of releases to air, water, and solid waste from the overall mass balance to the total of mercury releases determined by summing the individual products, sectors, and processes. This is useful because there are large uncertainties associated with many of the estimates, and two independent estimates can increase the confidence level of the results.

2.2. Identifying Sources, Pools,[17] and Flows

A mercury mass balance developed by William Fitzgerald and Joel O'Connor provided the framework to identify the major flows of mercury into the Watershed and specifically into the Harbor.[18] This framework was used to constrain estimates of inputs from specific sources and was critical to the next step of looking specifically at methylmercury entering the Harbor. The mass balance also pointed to the three major sinks for mercury, namely, water, air, and solid waste. This, in turn, pointed to the need to identify the specific sources of mercury to the air, water, and solid waste. Identifying the sources was accomplished by discerning which sectors, products, and processes were purposely or inadvertently using or processing mercury or mercury-containing materials, and

12. Members of the Mercury Action Group were Joanna Burger (Rutgers), William Fitzgerald (UConn.), Michael Gochfeld (RWJ Medical School), Joel O'Connor (SUNY), Donna Riley (EPA), and Valerie Thomas (Princeton). Members of the Methylmercury Action Group were Nada Marie Assaff-Anid (Manhattan College), Janina Benoit (Wheaton College), Michael Connor (NE Aquarium), Charles Driscoll (Syracuse Univ.), William Fitzgerald, Carlton Hunt (Battelle Ocean Science, Inc.), Robert Mason (Univ. of MD), and Joel O'Connor. Susan Boehme, Allison L. C. de Cerreño, Marta Panero, and Charles Powers also were members of each group.
13. See Janina M. Benoit, "Methylmercury Cycling in the NY/NJ Harbor: Implications for Mitigating High Mercury Levels in Harbor Fish," developed for and presented at a combined meeting of the Mercury and Methylmercury Action Groups, New York Academy of Sciences–NYAS (August 2001).
14. For a quick, but excellent primer on industrial ecology, see Reid J. Lifset, "Full Accounting," *The Sciences* (May/June 2000): 32-37; for links to work in industrial ecology, see the International Society for Industrial Ecology's website at www.yale.edu/is4ie; also check the *Journal of Industrial Ecology.*
15. See William F. Fitzgerald and Joel S. O'Connor, "Mercury Cycling in the Hudson/Raritan River Basin," developed for and presented at the NYAS Harbor Consortium meeting (February 2001).
16. See Nickolas J. Themelis and Alexander F. Gregory, "Sources and Material Balance of Mercury in the New York–New Jersey Harbor," developed for and presented at a combined meeting of the Mercury and Methylmercury Action Groups, NYAS (October 2001). Also see Susan Boehme and Marta Panero, "An Industrial Ecology Analysis of Mercury in the New York/New Jersey Harbor," presented at the NYAS Harbor Consortium meeting (June 2001).
17. The term "pool" is used in the document instead of the more commonly used "sink" because the latter implies that mercury gets trapped in a particular location. However, as is discussed later, mercury often moves from one of these pools to another as a result of various processes.
18. Fitzgerald and O'Connor, "Mercury Cycling in the Hudson/Raritan River Basin."

THE CYCLE OF SLUDGE

Sludge is a combination of organic matter, nutrients, and bacteria. It provides ideal conditions for methylation of mercury. As wastewater enters a publicly owned treatment work (POTW), the first step is the settling out of particles, leading to the creation of sludge. Secondary treatment of the separated water with chemicals, bacteria, and/or aeration further results in a bacterial sludge that is then combined with the primary material. Whereas the remaining water is released to the Harbor or other water bodies, sludge is removed. In New Jersey, one-quarter of the sludge is combusted, with the resulting ash disposed of as solid waste. In New York State, approximately half the sludge is dewatered and pelletized, and then used as fertilizer. The remainder is incinerated or buried. If mercury is present in the initial wastewater flow, the ash and pelletized fertilizer may remain contaminated.

then tracking such mercury through the life cycle of the product or process.

In most cases, the data presented here are based on regional (state, county, city) measurements or estimates that have been scaled using population data to the whole watershed region. In other cases, national data were used and scaled to population.[19] In general, the major Hg inputs have been extensively considered; however, there are some notable exceptions that are discussed in the "Gaps in Our Knowledge" section. Every effort was made to quantify the distribution of the mercury between the three major pools, namely, wastewater, air, and solid waste (landfills/monofills). This is an important step to determine which pathways are contributing the greatest amount of mercury to the Harbor. In some cases, mercury can first be released to one pool and then end up in a different pool. For example, mercury released to wastewater enters the publicly owned treatment works (POTWs)[20] and can settle out into the sludge (70–95%) or be transported out to the Harbor or nearest river (5–30%).[21] The sludge, in turn, can be combusted, used as fertilizer/land amendment, or buried either inter- or extraregionally. However, sludge within the POTW itself provides an excellent environment for methylating mercury.[22]

Recognizing that the ultimate goal of this effort is to develop pollution prevention strategies, we have chosen to differentiate the major releases of mercury as sectors and products. This is critical to developing solid pollution prevention strategies because the point of intervention and the means for intervention may be different for products (some of which may be manufactured in other regions but used and disposed of in the Watershed) and sectors (which utilize mercury in production or service). Mercury released from combustion processes are treated separately because they result from the inadvertent release of mercury during energy production.

Table 1 shows the estimates of mercury released from the major products and sectors.[23] It is estimated that approximately 10,650 kg of mercury are available for release each year to the water, air, and solid waste in the NY/NJ Harbor and its watershed. (This is in excellent agreement with Fitzgerald and O'Connor's estimate of 10,600 kg/yr for the region based on the national estimate adjusted for population.[24]) In some cases, this mercury is released directly to one pool, for example, automobiles release mercury to the atmosphere during fuel combustion. In other cases, the pathway is more complicated. For example, mercury in products and chemicals in hospitals can volatilize, enter the wastewater stream, or be disposed of in solid waste. Some processing facilities have controls in place to trap mercury such as Waste-To-Energy facilities (WTE). The mercury then is transferred to an ash that is typically buried in monofills or landfills. Other processes, such as wastewater treatment facilities, electric arc furnaces (EAFs), and regular landfills have no controls in place to collect the mercury. Thus, column 5 of Table 1 describes the different pools into which mercury from each source can flow. The pathways for mercury from each sector and product are detailed in the following sections.

19. The source of the data is given in the individual tables shown in Appendix 6.2.
20. POTW is utilized throughout the document instead of the more general wastewater treatment plant (WWTP). The latter designation includes any end-of-pipe facility installed to control effluents, whereas POTW refers only to those owned and operated by city or state agencies.
21. Philip Heckler (NYC DEP), personal communication, September 2001.
22. Benoit, "Methylmercury Cycling in the NY/NJ Harbor," p. 3.
23. A short description of how each number was obtained is given in Appendix 6.1, and a complete description of the calculations is shown in Appendix 6.2.
24. Fitzgerald and O'Connor, "Mercury Cycling in the Hudson/Raritan River Basin," p. 3, Table 1.

In several cases, the error bars associated with the figures in Table 1 are large. Thus, Figure 1 graphically depicts the errors associated for each of the key sectors and products in Table 1.

Although landfills and monofills account for the largest pool of mercury released in the Watershed (~7,000 to 10,000 kg/yr),[25] much of this appears to be at least temporarily sequestered, and thus, only a small fraction leaches out, with a smaller amount likely to make its way into the Harbor.[26] Conversely, 5 to 30% (~125–750 kg/yr) of the mercury that makes its way into the wastewater stream eventually ends up in the Harbor.[27] Furthermore,

TABLE 1. Hg Releases in the Watershed (kg/yr)[a]

	(Kg/yr)	Confidence Level[b]	Error (%)[c]	Released to[d]
SECTORS				
Automobiles/fuel combustion	150	Medium/low	60	A
Crematoria	25	Medium	50	A
Dental facilities	4,000	Medium/low	60	A, WW, SW
Hospitals	1,400	Low	70	A, WW, SW
Households: Furnaces	200	Medium/low	60	A
Products/waste	250	Low	70	A, WW, SW
Thermometers	500	Medium/low	60	A, WW, SW
Industrial/commercial furnaces	350	Medium/low	60	A, SW
Laboratories	600	Low	70	A, WW, SW
Utilities: Furnaces	400	Medium	50	A, SW
PRODUCTS				
Batteries	100	Low	70	A, WW, SW
Fluorescent lamps	700	Medium/low	60	A, WW, SW
Switches (appliances)	25	Low	70	A, SW
Switches (vehicles)	900	Low	70	A, SW
Switches (lighting)	100	Medium/low	60	A, SW
Thermostats	600	Medium/low	60	A, SW
Subtotal	**10,250**			
OTHER				
Religious/cultural use[e]	400	Very low	90	A, WW, SW
Total Hg available for release	**10,650**			

a A brief description of how these numbers were calculated is given in Appendix 6.1 and detailed in Appendix 6.2.

b Confidence level is based on how many independent estimates were available, rigorousness of the data collection, and how recently the data were gathered.

c Error percentages associated with confidence levels are within the ranges of other studies such as the NJ Mercury Task Force, The Pollution Prevention Partnership, and the Milwaukee Metropolitan Sewerage District (MMSD), Mercury Sector Assessment for the Greater Milwaukee Area (September 1997). Low=70%, Medium=50%, High=30%.

d Sector and product releases of mercury can be initially disposed of via air, wastewater, and solid waste. During processing of that waste, the mercury can be diverted or converted to a different pool. For example, auto switches sent to an EAF will combust the mercury releasing it to the air. Some of the mercury may end up associated with flue ash and be disposed of in landfills. Appendix 6.1 describes the estimates for the actual releases of mercury to air, landfills, and wastewater and Appendix 6.2 shows the calculations used to obtain the sector and product mercury releases. A, air; WW, wastewater; SW, solid waste.

e This estimate is the low end value estimated by Fitzgerald and O'Connor, "Mercury Cycling in the Hudson/Raritan River Basin." Given the large error bars and the lack of a full understanding of the extent of the problem and no data on how this mercury makes its way to the Harbor, religious and cultural uses will not be dealt with further in this document.

25. See Appendix 6.1

26. The leachate from landfills was calculated based on the estimates of the NJ Mercury Task Force (M. Aucott, personal communication). Their estimate was scaled to the population of the watershed. This is likely higher than the actual since not all mercury in leachate will eventually make its way to the Harbor.

27. For wastewater, the midrange figure for 20% is utilized for all further calculations.

FIGURE 1. Margin of Error for Estimated Mercury Inputs (kg/yr) to the NY/NJ Harbor

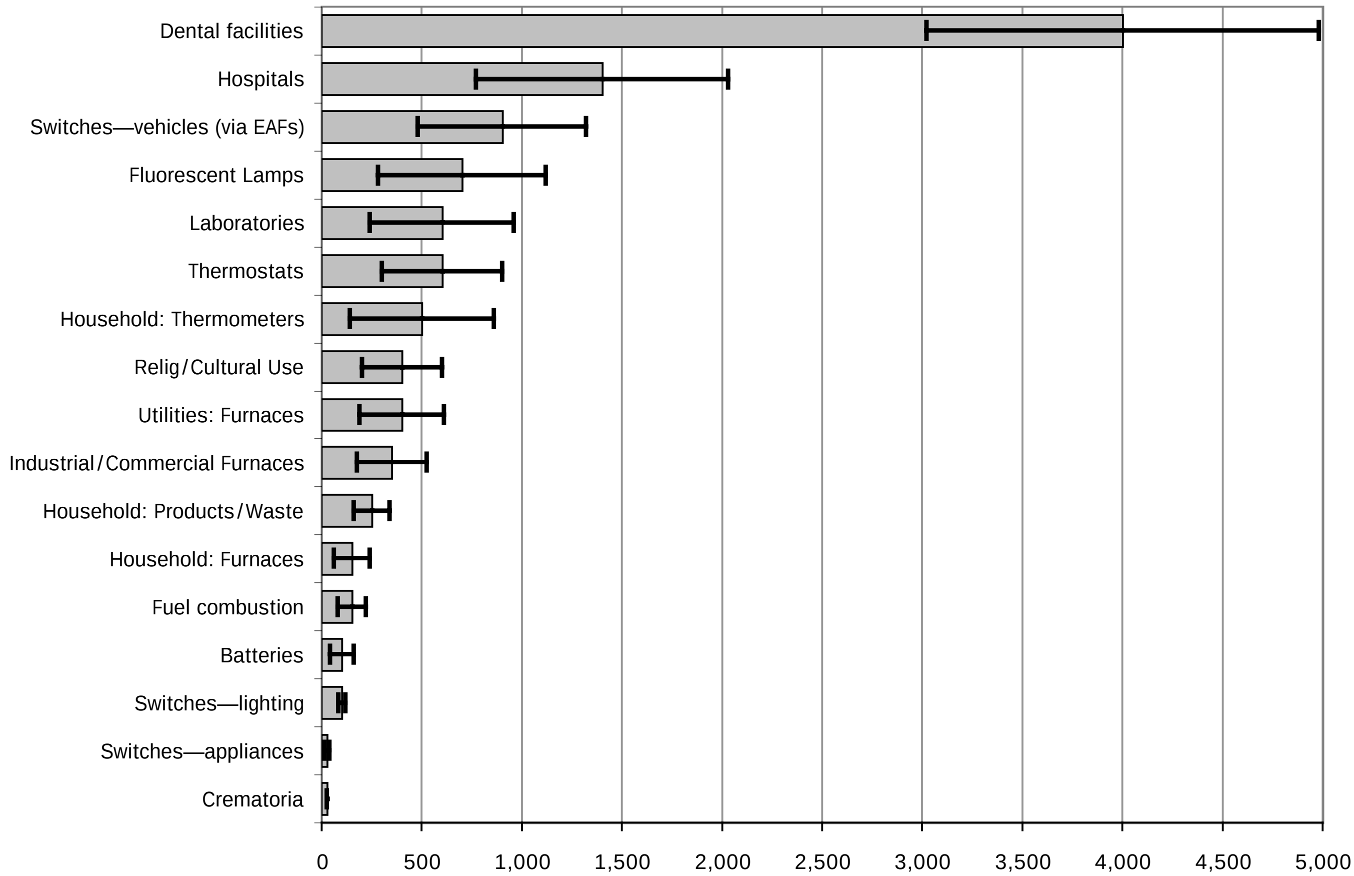
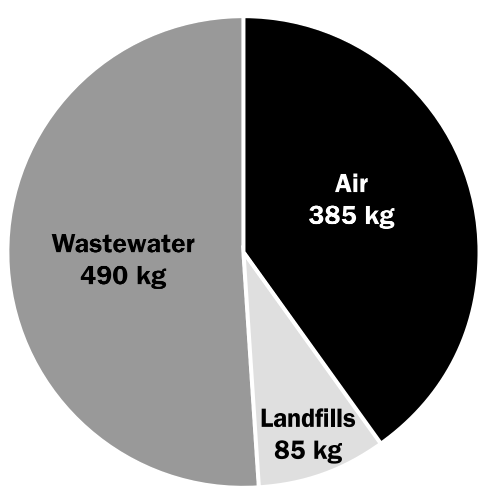


CHART 1. Kilograms Per Year of Mercury Entering the NY/NJ Harbor from Key Pools



Fitzgerald and O'Connor estimate that approximately 385 ± 245 kg/yr Hg[28] makes its way from the air to the Harbor after deposition on land, water bodies leading to the Harbor, or the Harbor itself. Thus, Chart 1 depicts the proportion of mercury each pool contributes, on average, to the total loadings on the Harbor each year.

Discharges of Mercury to Wastewater

Approximately 2,500 kg/yr of mercury are added to wastewater, and it is estimated that 5 to 30% of the mercury entering POTW facilities ends up in the Harbor, with the remainder staying in the sewage sludge. The sludge can then be pelletized and applied to fields as land amendment, buried or incinerated. All of these processes can re-release mercury (sometimes in the form of MeHg) to the environment, though not necessarily in the watershed. Measurements of mercury influent concentrations from New York POTWs, scaled to the watershed population agree well (~2,450 kg/yr)[29] with the estimate of 2,500 kg/yr based on the summing of all sectors and products adding mercury to wastewater.

As noted previously, MeHg is the form of mercury of most concern in the Harbor. To identify the major sources of MeHg to the Harbor, Benoit utilized available methylmercury data and the mercury budget of Fitzgerald and O'Connor, which helped identify the major pools of MeHg (sediments, river water and wastewater effluent), but not the pathways of methylation. In an effort to determine where methylation was occurring, Benoit analyzed the controls on methylation (presence of oxygen, sulfide, and organic matter) and how different conditions in the Harbor (eutrophication, mercury loading) might affect mercury concentrations in fish. The data suggest that when mercury enters the Harbor, some amount will be converted to MeHg because the conditions for methylation exist in the Harbor. Further, direct inputs of MeHg are of special concern because they provide a direct pathway for uptake by organisms. Benoit used a 0.4% methylation rate for Hg entering the Harbor from riverine input.[30] For mercury released from POTW, this percentage is much higher (1.3%) because these facilities provide the ideal conditions for methylation[31] (Table 2 and Chart 2). Thus, the importance of mercury entering the Harbor is amplified because of the higher rates of methylation. It is difficult to assess the importance of landfill/monofill leachate to MeHg input; however, conditions within the landfills are also thought to be conducive to methylation and therefore the higher percentage of 1.3% was used.

TABLE 2. Estimated Contributions of MeHg from Key Pools[a]

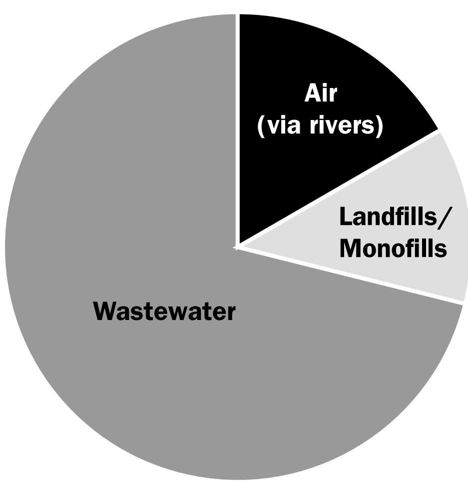
Pool	Hg Pool Size (kg/yr)	% Methyl-ated	MeHg (kg/yr)	± Error %
Air	385 [b]	0.4	1.5	60 [b]
Wastewater	490 [c]	1.3	6.4	75 [c]
Landfills	85	1.3	1.1	70 [c]

a See Chart 1 and text for source of these numbers.

b Based on Fitzgerald and O'Connor's estimate of 385 ± 245 kg/yr entering the harbor via air deposition.

c See Table 3 for estimate and error calculation of this value.

CHART 2. Proportion of Methylmercury Contributed to the Harbor by Each Pool



Therefore, two key scientific recommendations resulting from the methylmercury research are to:

- Decrease total mercury discharges to the waters of the Harbor and its watershed; and,
- Decrease discharges from wastewater treatment plants because they are a potential source of methylmercury.

28. This figure is derived from Fitzgerald and O'Connor's work in "Mercury Cycling in the Hudson/Raritan River Basin," p. 20.
29. Simon Litten (NYS DEC), personal communication; Nickolas Themelis (Columbia Univ.), personal communication.
30. Benoit, "Methylmercury Cycling in the NY/NJ Harbor," p. 2.
31. Ibid.

In practical terms, both these recommendations point to the need to decrease total mercury inputs to wastewater because this is the most direct methylmercury pathway to the Harbor. Thus, this should be considered the highest priority for developing P2 plans for mercury in the Harbor. Table 3 shows mercury discharges into wastewater by sector and product and the distribution of discharges to effluent and sludge.

For decreasing mercury inputs to wastewater, it is critical to backtrack to the sources of mercury and understand how it makes its way into the waters of the Harbor and its watershed. Figure 2 provides a graphic detailing the mercury pathway from industries and products through the POTWs and into the Harbor. (Relative amounts of mercury contributed are reflected in the weight of the directional arrows.)

Three key sectors account for over 80% of the mercury entering the POTWs. Dental facilities release amalgam particles during the process of placing and removing mercury amalgams for tooth fillings, leading to discharges amounting to 1,000 kg/yr of mercury. Non-hospital laboratories, which have mercury in numerous chemicals and reagents, discharge 400 kg/yr of mercury. Hospitals discharge another 700 kg/yr mercury through laboratories, measuring devices and instruments. (Some hospitals also have dental facilities.[32]) Other sources of mercury to POTWs are households. Households contribute an additional 350 kg/yr from human waste, mostly in the form of urine and feces but also from broken thermometers, cleansing products and laundry water (dyes, dirt).[33] Of these inputs, as noted previously, 5 to 30% of the mercury eventually makes its way into the Harbor. Chart 3 shows the proportional distribution by sector of mercury inputs that enter the Harbor via POTWs.

Emissions of Mercury to Air

It is clear that wastewater provides the most direct pathway for methylmercury to enter the Harbor. However, as it settles in Harbor surface sediments and then is methylated, inorganic mercury entering the Harbor via river

TABLE 3. Discharges of Mercury to Wastewater by Sector and Product in the NY/NJ Harbor Watershed and Actual Distribution of Discharges to Effluent and Sludge

		Discharges by Sector and Product (kg/yr)	Percentage That Flows to Wastewater	Amount That Flows to Wastewater (kg/yr)	Error (%)
SECTORS					
Dental facilities		4,000	25	1,000	60
Hospitals		1,400	50	700	70
Households:	products, waste	250	100	250	60
	Thermometers	500	20	100	60
Laboratories		600	67	400	70
Total		**6,750**		**2,450**	
Releases from POTW as effluent (5–30 % of influent[a])				490	75[b]
To Sludge (remainder)				**1,960**	**75**

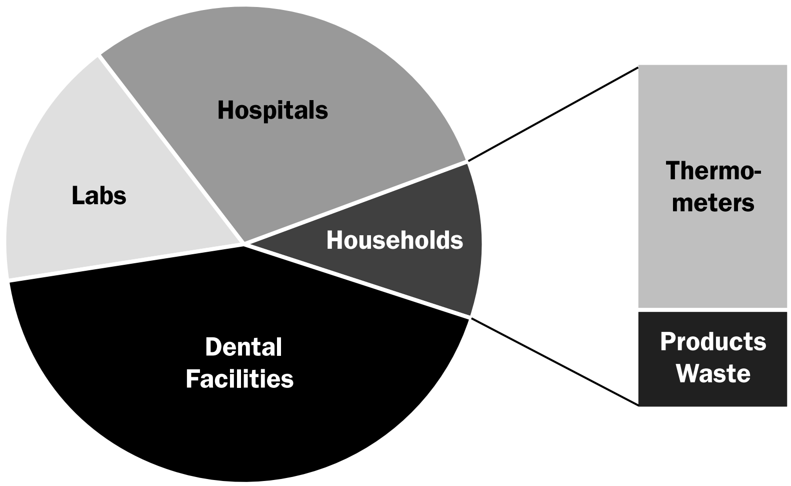
a An estimate of 20% of Hg in the influent is released as effluent-with the remainder staying in the sludge. This is based on estimates of 5–15% from personal communication with P. Heckler, NYC-DEP and Simon Litten, NYS-DEC; 28%, 1998 Headworks Analysis, NYC-DEP; and 30%, Themelis and Gregory. Higher releases during wet weather events account for the higher estimates of the POTW effluent range.

b Error estimate based on range of 5 to 30% of mercury may be released to Harbor in effluent.

32. Mercury released by hospital laboratories is counted within the hospital sector because administratively it would be the hospital that would implement pollution prevention strategies and bear any associated costs.

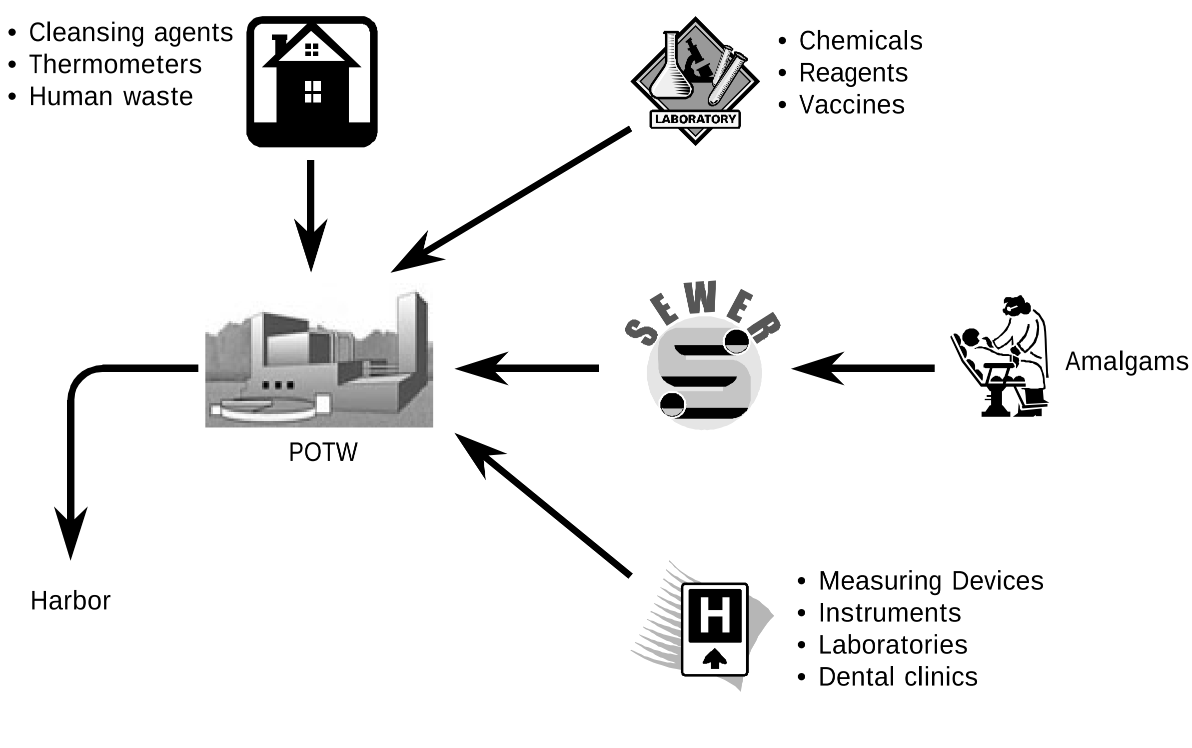
33. Association of Metropolitan Sewage Agencies (AMSA), *Evaluation of Domestic Sources of Mercury* (Washington, DC: AMSA, 2000); Philip Heckler and Ronald Lochan (NYC DEP) personal communication, October 2001. Veterinaries also contribute a very small proportion of mercury as a result of their use of thermometers and vaccines containing mercury. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (MMSD), *Mercury Sector Assessment for the Greater Milwaukee Area* (September 1997), http://www.epa.gov/glnpodocs/milwaukeehg/mercuryr.pdf.

CHART 3. Share of Mercury Discharges via Wastewater into the Harbor by Sector



water is also a possible source of methylmercury. Inorganic mercury is derived from atmospheric emissions that are deposited throughout the Watershed and then washed into rivers or deposited directly on rivers. Mercury also settles on land and then washes onto nearby water bodies during storm events. Summing the actual atmospheric emissions by sector and product leads to an estimate of nearly 2,000 kg/yr of mercury released within the Watershed (see Appendix 6.1). Fitzgerald and O'Connor estimate 1,240 ± 315 kg/yr[34] of mercury is released locally into the air, of which about 30% is deposited within the Watershed. Approximately 360 ± 60 kg/yr of mercury are deposited from longer-range sources outside the region. From the portion of mercury deposited in the Watershed from air, Fitzgerald and O'Connor estimate that 385 kg/yr of mercury actually

FIGURE 2. The Pathway of Mercury Through the POTWs and into the Harbor and its Watershed



34. They estimated 910 ± 315 kg/yr from major combustion processes and 330 ± 132 kg/yr from soil emissions. See Fitzgerald and O'Connor, "Mercury Cycling in the Hudson/Raritan River Basin," pp. 18–20.

enters the Harbor via rivers, rainwater, and runoff. Thus, after wastewater, atmospheric inputs are the next largest source to the Harbor and decreasing atmospheric inputs to the Harbor is a second priority. Because atmospheric inputs from beyond the watershed also add to this pool (coal combustion in the Midwest, for example), large-scale solutions are needed to significantly decrease these inputs.

The three major processes releasing mercury to the atmosphere are combustion, incineration, and volatilization. Incineration is the process that burns mercury-containing compounds or products, converting mercury in the solid phase to gas or airborne particles. Combustion refers to the burning of fuels (coal, gas, oil, wood), which contain trace amounts of mercury. The Themelis and Gregory report and data from Fitzgerald and O'Connor focus on the combustion sources of mercury to the air.[35] Several combustion processes can release mercury to the atmosphere. Many industries are required to control emissions of mercury, but capture rates vary. For example, medical waste incinerators collect approximately 95 to 98% of the mercury, which ends up in monofills or landfills, releasing only 2 to 5% to the air. However, coal combusting utilities only capture approximately 50% of the mercury with particles, leaving much of the mercury to be released to the atmosphere.[36]

Incineration involves the burning of materials to reduce their volume or to convert organic material to inorganic forms (medical waste, crematoria, waste-to-energy). This process also converts solid phase mercury to a gaseous or airborne phase. Volatilization of mercury is an important consideration because it is not stable as a liquid at normal pressures and temperatures and slowly evaporates. Thus, when fluorescent lamps, manometers, thermometers, etc. break, there is an opportunity for the mercury to vaporize. It is estimated, for example that nearly 25% of the mercury in fluorescent lamps volatilizes at the landfill before burial (assuming all lamps break).[37] Laboratories, hospitals, and crematoria all have been cited as having air concentrations of mercury that are higher than normal because of their use of mercury-containing products. Table 4 shows emissions to air from sectors and products in the NY/NJ Harbor Watershed.[38] The top three sectors that continue to emit mercury into the air are power-generating utilities (through combustion of coal and heavy oil in furnaces), industrial and commercial endeavors (again through furnaces), and the automotive sector (through both internal combustion of gasoline and auto switches products which end up in EAFs). Among the products of most concern are auto switches (mentioned above) and fluorescent lamps (from which the mercury volatilizes when the lamps are broken).

TABLE 4. Estimated Emissions of Mercury to Air by Sector and Product in the NY/NJ Harbor Watershed

	kg/yr
SECTORS	
Automobiles/fuel combustion	150
Crematoria	25
Dental facilities	101
Hospitals	114
Households: Furnaces	150
Products, other	17
Thermometers	61
Industrial/Commercial furnaces	350
Laboratories	44
Utilities: Furnaces	400
PRODUCTS (INCINERATED)	
Batteries	1
Fluorescent lamps	181
Switches (appliances)	8
Switches (automobiles)	300
Switches (lighting)	1
Thermostats	7
Total	**1,909**

Figure 3 provides a graphic detailing the pathway of mercury from various sectors through various types of incinerators (medical waste incinerators MWI; municipal waste incinerators MWC; crematoria; waste-to-energy WTE), and into the air. The incineration pathway was chosen to highlight because it is one where there are numerous points of leverage for pollution prevention. (Relative amounts of mercury contributed are reflected in the weight of the directional arrows.)

35. Ibid.; Themelis and Gregory, "Sources and Material Balance of Mercury in the NY/NJ Harbor," pp. 12–17.

36. Some utilities in the watershed only *distribute* energy (electricity) and may be purchasing the energy from companies generating it outside the region (some of which may utilize coal). Thus, demand in this region may contribute to mercury releases in other parts of the country as well.

37. Michael Aucott (NJ DEP), personal communication.

38. See Appendix 6.1 for full description of mercury releases from initial release through intermediate processing to final release.

FIGURE 3. The Pathway of Mercury Through Incinerators in the Harbor and Watershed, into the Air, and onto Land and Water[39]

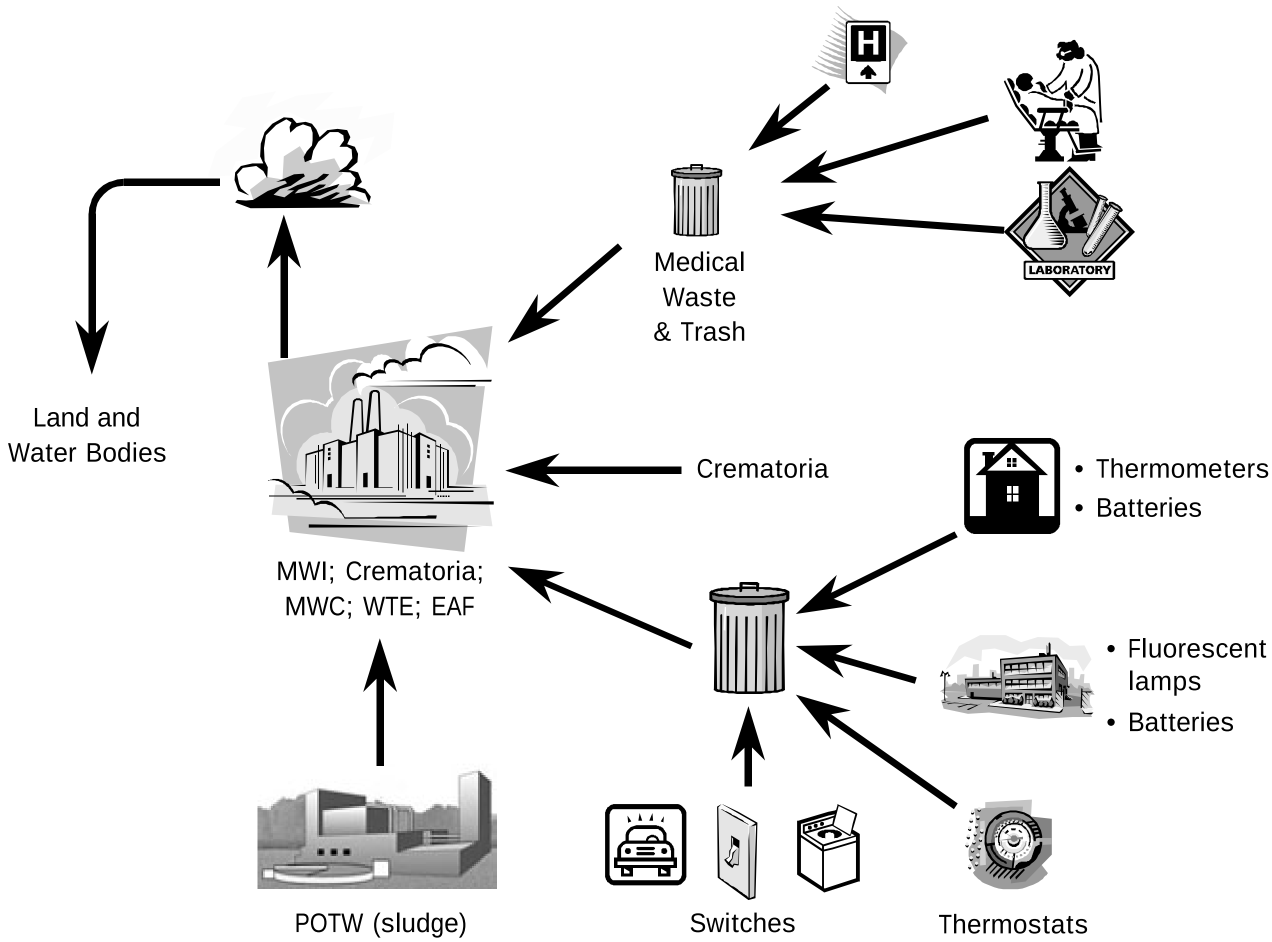


Chart 4 shows the proportional distribution by sector and product of mercury inputs to air in the NY/NJ Harbor and its watershed. Household emissions shown by sector are from the use of furnaces only. Emissions from the use of fever thermometers are included under the product figures. Similarly, auto switches are accounted for separately from automobile emissions. This is done to facilitate the development of P2 strategies, which in each of these cases may be different for the specific products than for the sectors in which they are utilized.

Releases of Mercury to Solid Waste

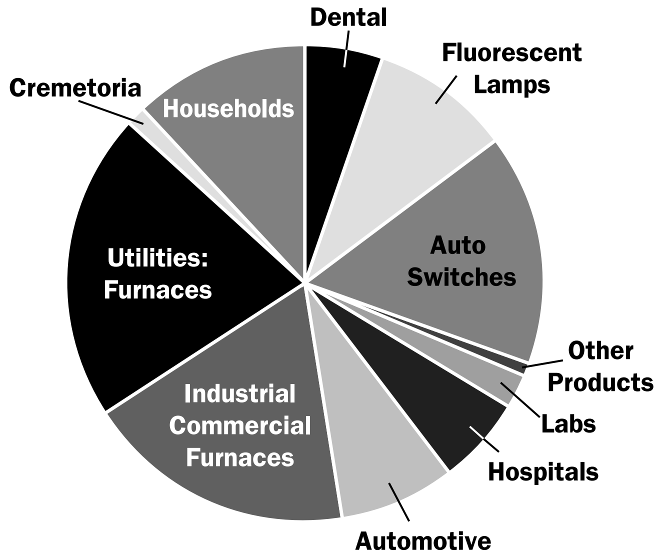
The third mercury pool is solid waste, with the end point being landfills and monofills. Themelis and Gregory estimate that 9,400 kg/yr of mercury is landfilled in the Watershed.[40] We can account for approximately 6,800 kg/yr based on the estimates for the individual sources. The difference is most likely caused by a range of medium to small sources (e.g., various household products that contain mercury, construction and demolition materials that are landfilled) whose mercury contents are not well quantified. Figure 4 depicts the mercury pathway by sector and product to landfills and monofills. (Relative amounts of mercury contributed are reflected in the weight of the directional arrows.)

Estimating releases of mercury from landfills is difficult because there is a paucity of data. Moreover, tracing mercury in leachate specifically to the landfill is problematic.

39. See Fitzgerald and O'Connor, "Mercury Cycling in the Hudson /Raritan River Basin."

40. Themelis and Gregory, "Sources and Material Balance of Mercury in the NY/NJ Harbor," p. 24.

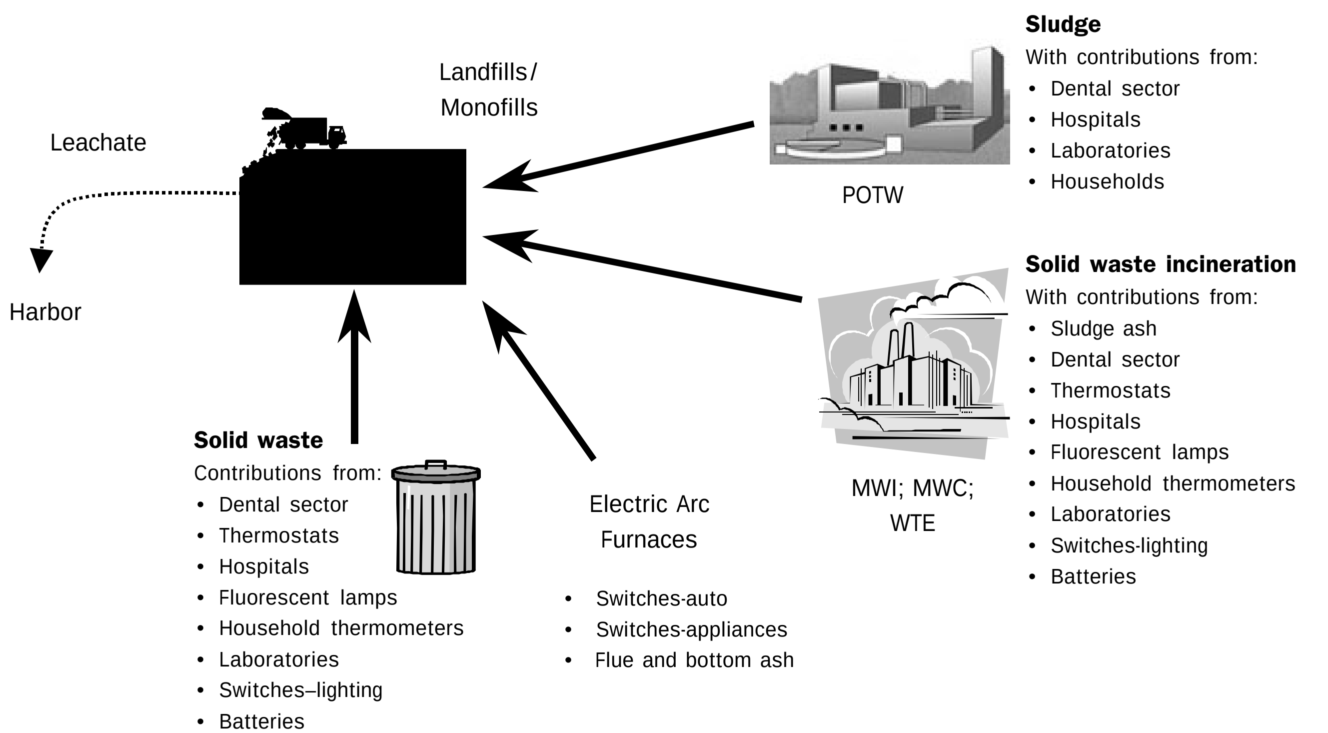
CHART 4. Share of Mercury Emissions to Air by Key Sectors anW Products in the NY/NJ Harbor watershed



It is possible, for example, that the leachate was contaminated by rainwater or as it moved through mercury-laden soils beyond the landfill. Nevertheless, the NJ Mercury Task Force data suggest that little mercury is leaching out of landfills and only small quantities are emitted to the atmosphere.[41] Furthermore, it appears that the mercury present in landfills is sequestered, at least on time scales of landfill use. Thus, it makes sense to accord the pathways of mercury leading to landfills a lower priority than the pathways leading to wastewater and air.

The key products and sectors of concern with respect to mercury releases to landfills and monofills are dental offices, which account for nearly 50% of the total releases to solid waste; hospitals, which account for close to 15%; fluorescent lamps, thermostats and automobile switches, which contribute approximately 10% each to landfills and monofills. Table 5 shows the full breakdown by sector and product of the mercury making its way into landfills and monofills in the Harbor watershed. Chart 5 depicts the proportional distribution.

FIGURE 4. The Pathway of Mercury to Landfills/Monofills and into the Harbor



41. Michael Aucott (NJ DEP), personal communication.

CHART 5. Share of Mercury Releases into Landfills/Monofills

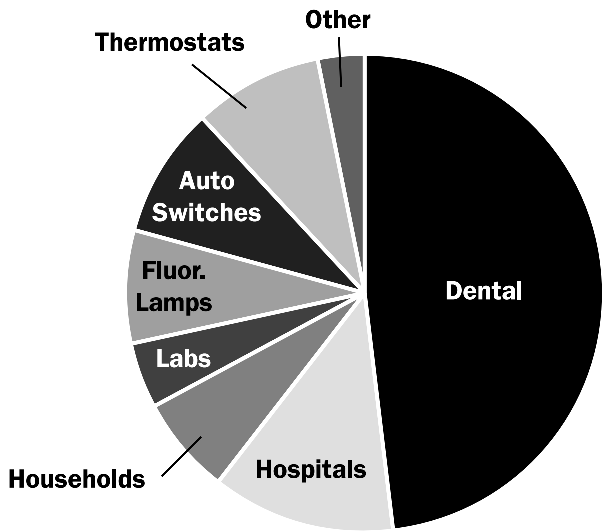


TABLE 5. Estimated Releases to Landfills/Monofills in the NY/NJ Harbor Watershed

	kg/yr
SECTORS	
Dental facilities	3,263
Hospitals	841
Households: Products, Waste	75
Thermometers	376
Laboratories	302
PRODUCTS	
Batteries	99
Fluorescent lamps	519
Switches (appliances)	17
Switches (auto)	600
Switches (lighting)	99
Thermostats	593
Total	**6,783**

2.3. Gaps in Our Knowledge

As noted by Fitzgerald and O'Connor several of the largest industrial users of mercury were located on the shores of the Harbor. Many of these sites, especially the areas on the western side of the Harbor including Newark Bay and the Passaic and Hackensack Rivers remain heavily contaminated with a range of pollutants including mercury. There are numerous brownfields and Superfund sites along these rivers.[42] Superfund sites include, for example, Diamond Alkalai, PJP Landfill, and Syncon Resins, all of which are cited specifically for mercury or heavy metals. Mercury concentrations are monitored at some locations in the soil and groundwater. However, there are no studies of how much of this mercury eventually makes its way into the Harbor. Thus, whereas this input could potentially be large, without sufficient useable, historic, recent or ongoing water column or sediment measurements at these sites, it is impossible at this time to estimate (or even guesstimate) the amount of mercury (or other contaminants) flowing to the NY/NJ Harbor from these sites. Nevertheless, given the potential loadings from these sources it is recommended that these sites be targeted for future studies to determine whether they need to be factored in to mercury P2 plans for the Harbor. In the meantime, the Consortium should move forward on decisions based on the present state of knowledge. The Academy will continue to try to gather more information about these sites and present this when and if it becomes available.

Other products that may be contributing mercury to the Harbor are plumbing gauges and dairy manometers. Because programs are underway to collect and retire these devices, it was assumed that they would not be adding additional mercury to the Harbor. We were unable to gather sufficient data to evaluate the success of these programs. Further research may be needed.

Mercury-bearing gauges, equipment and chemicals in schools may also contribute to mercury releases to the Harbor. A national campaign to educate school administrators about mercury-containing products and chemicals from schools is ongoing. An estimate of how much mercury is in any given school varies greatly and could not be extrapolated to the Watershed.

In addition to the gaps in knowledge noted above, there are several other areas that require further study. More data are needed, for example, on the percentage of methylmercury in wastewater, mercury emissions from fuels, and the amount of mercury transported via sediments from upstream regions into the Harbor. The infor-

42. See the "Industry" section in Fitzgerald and O'Connor, "Mercury Cycling in the Hudson/Raritan River Basin," pp. 7–11, for site descriptions, historical activity, and some soil and groundwater mercury concentrations.

mation derived from a study of any of these could lead to some modifications in the proposed recommendations.

2.4. Summary of the Pathways

The estimates on mercury releases to the three key pools (water, air, and landfills), combined with the recommendations for methylmercury[43] point to pollution prevention strategies that address wastewater first and foremost. It is within this priority that the dental, hospital, and laboratory sectors should be focused because they account for nearly two-thirds of the discharges to wastewater in the region.[44] In practical terms, the technology to trap and collect the mercury at the usage point in these sectors is already available, and in most cases non-mercury alternatives are also available. Pollution prevention strategies that address these sectors are the logical choices for implementation. Furthermore, POTWs provide the perfect conditions for methylation of mercury in the sludge materials. This also argues for decreasing mercury entering the plants, to decrease the amount of mercury and methylmercury that is released to the Harbor.

An added benefit to recycling or replacing mercury in the dental, hospital, and laboratory sectors is that this would also drastically reduce the amount of mercury sent to landfills and reduce air emissions as well. These three sectors account for almost two-thirds of the mercury that ends up in landfills and monofills as solid waste, sludge, and ash, and more than one-fifth of the mercury released to the air.

Table 1 demonstrates that the largest pool of mercury ends up in the solid waste stream and ultimately in landfills and monofills. Estimates of atmospheric release from landfills are low and leaching rates are also thought to be low for the major landfill (Fresh Kills) in the Watershed. However, conditions within landfills/monofills could be optimal for methylation, and thus the mercury that is leaching out will have a higher percentage of methylmercury. Therefore, any opportunities to reduce mercury inputs to landfills should be implemented when feasible. This is considered a lower priority than the wastewater recommendations, but technologies and strategies exist for recapturing/and or replacing mercury in several major contributors (switches in automobiles and other vehicles, appliances, lighting, household thermometers, thermostats, and fluorescent lamps) to landfills/monofills and should be encouraged.

Household products (bar soaps, dishwasher detergents, cleaning agents, greeting cards) contain trace amounts of mercury associated with dyes. Mercury switches are used in a range of products, including children's toys and shoes with flashing lights. Mercury can be avoided in many of these products and should be eliminated when possible. Labeling requirements for all products that contain mercury could help to discourage the use of these items.

The major source of mercury to atmosphere on a global scale is emissions from coal combustion. Although it is impractical to immediately halt coal combustion in the region, there are potential strategies to minimize mercury release by both pre-washing the coal and utilizing trapping technologies at the facilities. These steps could be undertaken while alternative, cleaner energy sources are implemented. (There is a downside to coal cleaning if the mercury removed is not effectively managed. See the box, "Coal Cleaning and Mercury: A Little Known Story," in Section 3.)

Several recommended priorities for action and further research are derived from the scientific analysis presented in this section, as follows:

Recommended Priorities for Action

- Decrease mercury discharges from wastewater
- Decrease atmospheric inputs of mercury
- Decrease inputs of mercury to landfills and monofills

Recommended Priorities for Research

- Develop data related to contaminated land-based sites in the Watershed
- Link initial findings on dredged materials to future contaminant studies

43. Benoit, "Methylmercury Cycling in the NY/NJ Harbor."

44. Mercury from religious/cultural use has been identified as a possible source to wastewater. There is, however, no quantitative data on the uses or releases of mercury from these practices. If future research indicates that this is a significant source of mercury to the Harbor, we recommend that a pollution prevention strategy be defined.

3. THE ECONOMIC, POLITICAL, AND SOCIETAL FRAMEWORK[45]

To develop pollution prevention plans for mercury that are likely to be implemented, the next step is to incorporate an economic analysis based on the scientific findings described in Section 2. Thus, this section first provides a broad view of the costs associated with mercury use in the New York/New Jersey Harbor and its watershed, as well as an overview of the benefits that would accrue (in terms of avoided costs) from preventing mercury pollution. Second, it specifically examines various alternatives (and associated costs) that could be used at the key leverage points identified by the scientific research. (To facilitate comparison between the different options, we developed a common index of cost per kilogram of mercury removed/avoided.) Third, it will make several recommendations based on the combined scientific and economic findings, informed by the findings from the survey of public opinion,[46] which will help prevent and/or reduce mercury pollution in the Harbor.

It is worth pointing out before the full discussion that with respect to public participation in the Watershed, there is evidence to suggest that residents are likely to want to be involved with certain pollution prevention and management measures. Further, in terms of responsibility, there is much support among residents for shared responsibility, especially by governments and businesses, but also by individuals themselves.[47] This last point is critical. Individual responsibility is important because mercury pollution is often associated with disposal of mercury-bearing products by end-users.

In the current climate, traditional market mechanisms to curb mercury use, such as price increases, are not an option because decreased demand over the last two decades has resulted in an oversupply in the market for mercury. This glut is likely to continue because opportunities to retire part of the circulating stock are currently unavailable.[48] Thus, educating consumers as to the environmental implications of their purchasing decisions may become a significant tool to signal the market to offer non-mercury alternatives.[49]

WHAT PEOPLE IN THE REGION ARE THINKING: SEVERAL RESULTS FROM THE PUBLIC OPINION SURVEY

During the spring and summer of 2001, the New York Academy of Sciences commissioned the Marist College Institute for Public Opinion to develop and implement a public opinion survey of New York and New Jersey residents of the Harbor and its watershed. The findings from the poll helped to determine both the most effective means for outreach and the likelihood that certain P2 strategies will be supported by the public.

Among the more interesting findings, 82% of respondents felt that one does not have to choose between a healthy economy and a healthy environment; it is possible to have both.

In terms of P2 strategies, 97% of respondents in the NY/NJ Harbor watershed always, often, or sometimes recycle, compared with only 83% nationwide.

With respect to sharing responsibility, 92% of respondents felt that business should bear a great deal or fair amount of responsibility; 92% also pointed to government. However, 86% believed citizen’s groups should also bear the brunt of responsibility, and 82% pointed to individuals as bearing a great deal or fair share of responsibility.

45. The dollar figures that appear throughout this section are rounded. For exact costs, see Appendix 6.3.

46. During the spring and summer of 2001, the Academy worked closely with Marist College Institute for Public Opinion to develop and conduct a public opinion survey of NY and NJ residents of the NY/NJ Harbor and its Watershed.

47. From the survey, we found that recycling rates in this region were high compared with national statistics, with 86% of respondents saying they recycled always (79%) or often (9%), compared with only 68% nationally (57% always; 11% often). Also, already, more than half of respondents in this region always seek to purchase energy-saving appliances, and close to one-third use nonchemical means for treating their lawns or killing pests. In terms of responsibility, 92% of respondents believed that government shared a great deal or a fair amount of the responsibility for dealing with such issues; 92% also felt business shared a great deal or fair amount of responsibility; and 82% of respondents felt they themselves shared the responsibility.

48. National stockpiles (DOE and DOD) are not accepting any more mercury. Currently there are no proven technologies to stabilize mercury so that it could be safely sequestered in landfills. Exporting mercury to other countries should also be discouraged, since its subsequent use and release may contribute to global emissions.

49. This may include requiring producers to label products that contain mercury.

3.1. The Broad Picture

The current annual cost range for the purposeful usage of mercury in products or services[50] identified in Section 2 as key leverage points for the NY/NJ Harbor Watershed[51] is estimated to be at least $132M–$1B (Table 6). Implementing a comprehensive mercury pollution prevention and management plan may be achieved by:

- Source elimination by materials/product/process substitution;
- Technology applications to capture mercury at point sources;
- Comprehensive recycling.

The cost of mercury pollution prevention for the products and sectors considered in this report varies according to options chosen, and not all options are available for each type of release. No technology for trapping or recycling mercury is able to attain 100% efficiency; only product substitution can totally remove mercury from the waste stream, and such substitution is not always feasible. Annual costs for each of these P2 and management strategies vary widely, ranging from at least $31.4M to $143M for product substitution, $170M to $849M for comprehensive recycling, and $14M to $82M for applying control technologies to prevent releases at the source.

In each case, cost, technological and administrative feasibility vary by sector and industry.[52] Several examples of the cost to capture mercury once it has been released from the source, rather than prevention prior to release, are described below:

- Installing technology to reduce mercury concentrations in effluents from a medium-sized POTW, for example, could cost more than $51.4 million in cap-

TABLE 6. Comparison of Costs of Mercury Pollution Prevention and Management Strategies for Sectors, Products, and Processes in the Watershed (in $1,000s)

	Cost Range of Using Hg Products/yr		Cost Range of Using Non-Hg Products/yr		Cost Range of Comprehensive Recycling/yr		Cost Range of Applying Applying MACT at the Source/yr for 5 yr		Cost Range of Applying MACT at Source/yr Thereafter	
SECTORS										
Crematoria	N/A		N/A		N/A		$2,500	$2,600	$270	$360
Dental sector	$2,600 [a]	$3,800 [a]	$12,200 [b]	$17,500 [b]	$660	$780	$10,000 [c]	$11,000 [c]	$3,000	$9,500
Hospitals	$5,600 [a]	$65,200 [a]	$4,400 [b]	$9,500 [b]	$7,200 [d]	$213,650 [d]	$920	$34,200	$340	$2,828
Laboratories	N/A		N/A		$4,400	$132,500	$504	$33,573	$162	$1,620
PRODUCTS										
Fluorescent lamps	$115,500	$967,970	N/A		$24,220	$24,230	N/A		N/A	
Switches –autos	N/A		N/A		$8,774 [e]	$13,381 [e]	$457 [f]	$604 [f]	N/A	
Household Thermometers	$1,547 [g]	$2,587 [g]	$3,237	$5,200	N/A		N/A		N/A	
Thermostats	$6,960 [h]	$23,200 [h]	$11,600	$111,360	$124,300	$464,000	N/A		N/A	
Total	**$132,207**	**$1,062,757**	**$31,437**	**$143,560**	**$169,554**	**$848,541**	**$14,381**	**$81,977**	**$3,772**	**$14,308**

a For dental sector, includes cost for mercury amalgam only. For hospital sector cost of using mercury products in labs were not available.

b For dental sector, includes cost for composite material only. For hospital sector cost of using non-mercury products in labs were not available.

c Cost per first year.

d Includes cost for dental solid waste recycling and laboratory recycling of all discharges, only.

e Cost to replace all mercury switches with non-mercury ones for the entire automobile fleet in the Watershed.

f Cost to replace all mercury switches with non-mercury ones only at end-of-life of automobiles.

h Cost for thermostat units only. Does not include comprehensive recycling cost.

50. This includes cost for purchasing mercury products only for most sectors considered in this document.

51. As defined in Fitzgerald and O'Connor, "Mercury Cycling in the Hudson/Raritan River Basin," p. 2.

52. Because mercury releases from one sector may be treated by public sector facilities, sector-specific costs and savings may not accurately reflect the overall societal economics of mercury use and release. Therefore, specific sectors and industries are examined separately and then aggregated for policy evaluation.

ital investment plus annual operating and maintenance expenses of more than $9.4 million for each plant.[53] Based on these estimates the cost of compliance annualized over 10 years is estimated to be $16.7M/yr. This translates into $1M/kg to prevent 450 kg of mercury from escaping POTWs per year, for ten years and then over $627K/kg of Hg per year afterwards.

- The cost of recovering mercury to prevent emissions from combusted solid waste, from medical waste incinerators and Waste to Energy plants ranges from $464/kg to $3,500/kg of mercury removed.[54]
- The cost for maximum available control technologies (MACT) applied at power-generating utilities (to prevent incidental releases from burning coal) may range from $18,600/kg to $36,000/kg of mercury recovered.[55]

From a society-wide perspective, it is costs such as those delineated above that would be avoided by pollution prevention approaches even though they may not be internally cost-effective for any one sector. Thus, reducing and eliminating mercury releases will require a concerted effort to apply a variety of techniques, driven by incentive and financing mechanisms that will better reflect the overall benefits to the regional environment and economy. For example, the Western Lake Superior Sanitary District (WLSSD) in Duluth, Minnesota, has worked to reduce mercury input to POTWs by assisting dentists in organizing a recycling collection program at a minimum annual expense and encouraging the use of filtration systems to reduce initial discharges to sewers.

Benefits

The mechanisms of mercury damage have been described in Section 2; here, that discussion is converted to an analysis of benefits in risk reduction. Many of the social and ecosystem benefits of preventing mercury releases to the environment are difficult to quantify in monetary terms. Nevertheless, contaminated fish may affect a large sector of the population, including recreational as well as subsistence (mostly minorities and low income) fishermen and their families. Pregnant women, young children, and those with weak immune systems are most at risk. A National Research Council report indicates that in the United States about 60,000 infants may be at risk for neurological damage from mercury exposure before birth, which suggests that each year approximately 3,500 infants could be at risk of being exposed in the Watershed region.[56] A 1997 U.S. EPA report indicates that among women of child-bearing age (15–44 years) in the United states, approximately 7% exceeded the reference dose (RfD)[57] for methylmercury, based on month-long projections of fish and shellfish intake, 1 to 3% were found to have methylmercury exposures three to four times the RfD. Furthermore, 25% of children were found to exceed the RfD, whereas 5% had exposures from ingestion of fish/shellfish two to three times the RfD.[58] Local food consumption surveys in New Jersey have estimated that greater than 20% of women of child-bearing age exceed the current RfD.[59]

In addition to impaired childhood development, mercury poisoning may cause neurological, kidney, and liver damage as well as nervous systems disorders affecting vision, speech, hearing and coordination.[60] Without attempt to quantify the value or quality of human life, it is clear that medical care for all affected individuals alone

53. ENSR Consulting and Engineering, "The Cost of Compliance of WLSSD with the Great Lakes Water Quality Initiative," draft presented for WLSSD, Duluth, Minnesota (1993), Doc. 7217-001-013; also Tim Tuominen (WLSSD), personal communication, November 2001. With a financial package secured, charges could amount to $16.7M per year for 10 years plus $9.4M per each subsequent year.
54. U.S. EPA, *Mercury Study Report to Congress,* v. 8, Part B, p. B-3 to B-8. The range depends on the technology used at each MWC. The cost effectiveness of applying activated carbon injection is about $211 to $870/lb, or $464 to $1914/kg removed. The costs of applying Carbon Filter Beds technology ranges from $1,230 to $2,378/kg recovered. Costs associated with application of Wet Scrubbing technology may be $3,500/kg. In general, these costs include capital recovery costs and operating and maintenance costs. The capital recovery factor is based on a 7% interest rate annualized over 15 years. In addition, most combustion processes produce residual flue ash-containing mercury, which may be re-released to the environment if not segregated from bottom ash and then sent to monofills. Charges for ash or contaminated soil sent to "nonputrescible" monofills range from $.025/kg to $.04/kg of mercury, depending on transportation costs to the site and space availability (Derek Veenhof, American Re-Fuel Co. of NY, personal communication, 10/16/01).
55. EPA, Mercury Study Report to Congress, v. 8. The cost range per kilogram given in this report has decreased considerably since this study was first published. We use the updated information provided by Ellen Brown, Office of Air and Radiation, EPA Headquarters, personal communication, 11/14/01.
56. National Research Council, *Toxicological Effects of Methylmercury,* pp. 325-327. Also, cited in Lester R. Brown, *Eco-Economy: Building an Economy for the Earth* (NY: WW Norton & Company, 2001), p. 132.
57. The reference dose (RfD) is the amount of methylmercury which may be ingested on a daily basis over a lifetime without anticipated adverse health effects to humans, including sensitive subpopulations. The current RfD for MeHg is 0.1 microgram/kg/day. At or below this level, exposures are expected to be safe. The risk following exposure above the RfD is uncertain, but risk increases as exposure to methylmercury increase.
58. Children have higher intakes of methylmercury, relative to body weight, than do adults. US EPA, *Mercury Study Report to Congress,* v. 4, EPA452/R-97-006 (December 1997), p. ES-3.
59. A.H. Stern, L.R. Korn and B.E. Ruppel "Elimination of Fish Consumption and Methylmercury Intake in New Jersey Population," *Journal of Exposure Analysis and Environmental Epidemiology* 6, 4 (1996): 503-525. This journal is published by the International Society of Exposure Analysis (ISEA), http://www.naturesj.com/jea/.
60. Lake Michigan Forum, et al. *A Guide to Mercury Reduction in Industrial and Commercial Settings* (July 2001), p. 3.

could represent an extraordinary expenditure. Furthermore, avoided liabilities for parties responsible for mercury pollution might also be significant in terms of monetary value.

An often-overlooked benefit of preventing pollution is to improve ecological health and avoid further deterioration of intricate networks of groundwater and surface water, wetlands, rivers and lakes. The NY/NJ Harbor's ecological system provides multiple ecosystem services–natural processes through which ecosystems sustain human life.[61] Such services range from offering natural systems for water purification, flood control, waste and organic matter decomposition and recycling, pest control, and moderation of climatic effects. Preventing or reducing mercury pollution will reduce contaminated runoff, which has an adverse effect on the health of local wildlife and fish populations as well as water quality throughout the watershed. As a point of reference, it would cost approximately $6 billion to build a new filtration facility to treat New York City's drinking water, plus $300 million per year for operating and maintenance fees. Instead, New York City has decided to protect its natural water-filtering ecosystem by investing in nature's services. Preventing run-off contaminated with mercury or (other toxicants) would guarantee the success of this initiative.[62] Finally, decreasing inputs of contaminants (including mercury) to the Harbor eventually will decrease the cost of managing approximately 2 million cubic yards of dredged material per year during regular maintenance of channels. The current cost of treating contaminated materials may range from $54 to $180 per cubic yard, depending on the level of toxicity and final disposition of the material.[63]

3.2. Cost, Technological and Administrative Feasibility for Key Leverage Points

The scientific research conducted under the New York Academy of Sciences' Harbor Consortium has identified key leverage points for preventing and/or reducing mercury pollution in the NY/NJ Harbor, which relate to specific sectors and products. For each, estimates of cost and net savings for preventing the release of mercury are assessed. Various options are considered, depending on whether mercury use is to be eliminated at the source, reduced, or managed in a safer manner. Building on the scientific findings, the following analysis focuses primarily on products and sectors that release mercury to wastewater and air, earlier identified as the top two priorities for P2 and management strategies in the Watershed.

Major Sectors Discharging Mercury to Wastewater

Dental facilities, laboratories, and hospitals account for nearly 90% of the mercury discharged to the sewer systems each year. Although the costs to install systems to prevent mercury in effluents for the Watershed region have not been calculated, the Western Lake Superior Sanitary District (WLSSD) in Duluth, MN performed such a study in 1993. Their cost estimates are utilized throughout this document, recognizing that the costs might be even higher in the NY/NJ Harbor watershed because many POTWs in this region deal with larger volumes of wastewater than in the Duluth example.[64]

Installing a system to treat non-sludge soluble mercury by chemical reduction/precipitation and ionic exchange at POTWs to prevent Hg discharges in effluents would cost approximately $54.4M for a medium-size plant.[65] Annual maintenance and operating charges add another $9.4M. With financing secured, the combined annual cost is more than $16.7M/yr for 10 years per POTW and then $9.4M per year thereafter.[66] There are at least 30 large POTWs in the Watershed, so the initial overall annual cost would be $500M for 10 years, decreasing to $282M for each subsequent year.[67] This translates to an initial annual cost of over$1M/kg of mercury that would prevent 490kg/yr from entering the harbor if controls are instituted at all POTWs, and such measures still do not treat the portion of mercury that ends up in the sludge at the POTW

61. RAND, Science & Technology Policy Institute, "Nature's Services: Ecosystems are More than Wildlife Habitat," http://www.rand.org/scitech/stpi/ourfuture/NaturesServices/section1.html.
62. Ibid.
63. Richard Larrabee, "Port Development: It Is a Balancing Act," presentation at the Metropolitan Waterfront Alliance, New York City (February 7, 2002).
64. The Duluth plant treats 40 million gallons each day, compared with approximately 78 million gallons/day (1.4 billion gallons/day divided by 18 NYC POTWs) at a typical POTW in New York City. Tim Tuominen (WLSSD), personal communication, November 29, 2001; Philip Heckler (NYC DEP), personal communication, November 2001.
65. ENSR Consulting and Engineering, "The Cost of Compliance of WLSSD with the Great Lakes Water Quality Initiative, p. 7-4. Also, Tim Tuominen, personal communication, September 2001.
66. Ibid. Based on the financing estimates for the plant in Duluth at an interest rate of 7%. With a financial package secured, charges could amount to $16.7M/year for 10 years, and $9.4M/year each subsequent year.
67. Ibid.

(70–95%). Thus, prevention and/or management measures focused on the sources of mercury (e.g., dental facilities, laboratories, hospitals, etc.) are less expensive and provide greater control over the amount of mercury entering the Harbor.

Recommended Priorities for Action to Reduce Mercury Inputs to Wastewater:

- Dental facilities
- Hospitals
- Laboratories

This is not to say that households, which account for nearly the same total input load as laboratories are not equally important. However, there are two reasons for not treating households here. First, because the mercury released from households is largely from human waste, it must be prevented from reaching humans in the first place. Second, mercury thermometers account for the balance of mercury released from households, and they are dealt with in detail later in this report.

Dental Facilities. Although mercury releases from dental facilities has decreased over the past decade, the dental sector still accounts for more than two-fifths of the mercury entering the Harbor and watershed through wastewater. Mercury is released from dental facilities during placement and removal of amalgams containing mercury. Although most dentists already utilize chair-side traps (0.7-mm mesh), and some use a liquid-ring vacuum pump system with a filter ranging from 0.42 to 0.84-mm pore size, it is estimated that 25 to 30% of small amalgam particles and soluble mercury continue to be discharged to the sewer system.[68] The practice of rinsing chair-side traps over sinks and drains further increases the mercury discharged to sewers.[69]

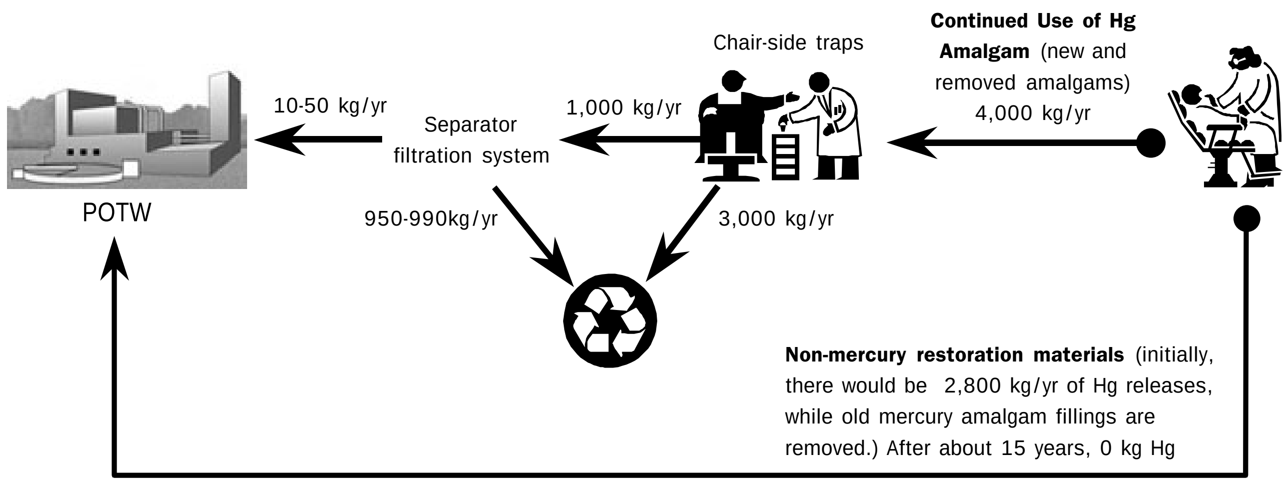
There are several points for potential intervention and several different types of intervention to prevent mercury from flowing from dental offices into the sewer systems and eventually to POTWs (see Figure 5). Each has different costs as well as technological and/or administrative hurdles. The account below provides detailed information about costs for avoiding water discharges from the dental sector. (For prevention and management measures related to solid waste, see the discussion on Dental Facilities under Landfills: Solid Waste Management.) The cost estimate for crematoria (which release mercury when amalgams still present in human remains are incinerated) is given in Appendix 6.2. No control options exist to prevent household discharges from mercury amalgams present in human waste (except amalgam substitution). Two options have been evaluated for the dental sector: (1) use of control technology to reduce mercury discharges; and (2) substitution of mercury amalgams by composite materials.

> ### SECTORS WORKING TOGETHER
>
> One P2 strategy implemented by the Western Lake Superior Sanitary District in Duluth, MN involves a program to promote Hg recycling by dental facilities. Rather than pay each time recycling is needed, each participating dentist is charged an annual fee of $50 for comprehensive recycling, lower than what it would cost if Hg was sent for recycling more than once per year. Dentists are also encouraged to install separator filtering systems.

Regarding control technology, from 95% to 99% of current discharges from dental offices to wastewater in the Watershed region (1,000kg) could be prevented by use of a separator filtering system, which may cost approximately $700/unit plus annual operating expenses of about $380.[70] The total cost of installing and operating this type of separator system at all dental offices using mercury in the Watershed would be between $10M and $11M/yr for five years and between $3M and $9.4M per each subsequent

68. Hazardous Waste Management Program, Water and Land Resources Division, Department of Natural Resources, *Management of Hazardous Dental Wastes in King County*, 1991-2000 (Seattle, WA: LHWMP, October 2000), http://dnr.metrokc.gov; Metropolitan Council Environmental Services (MCES) and Minnesota Dental Association, E*valuation of Amalgam Removal Equiipment and Dental Clinic Loadings to the Sanitary Sewer* (St. Paul, Minnesota: MCES, December 2001). Peter Berglund (MCES) has pointed out that virtually all new systems being installed today are turbine (dry) vacuum pump systems that do not have filters. As all models are replaced with the new (dry) system, the opportunity to collect additional amalgam discharged as wastewater is lost; Personal communication.March 29, 2002.
69. There is anecdotal evidence of an ongoing practice of rinsing chair-side traps in regular sinks, thereby releasing the caught mercury down the drain. However, the numbers related to this could not be confirmed. Therefore, the estimate here does not include this amount, though it could add additional mercury into wastewater. There is also anecdotal evidence of some of the mercury being placed in red medical bags, thereby making its way into the incineration process. Again, there are currently no confirmed numbers.
70. The average price of the separator system, which can serve six dental chairs, is $695 plus a one-time installation fee of $200. In addition, filters need to be replaced at least twice a year. Each new cartridge costs approximately $150 and shipping the used unit directly to the recycler by common carrier costs $40. Owen Boyd (SolmeteX Co., MA), personal communication.

FIGURE 5. Intervention Points to Prevent the Flow of Mercury from Dental Offices to the Harbor via Wastewater



year if dentists chose to manage and send the used filter cartridges directly to the recycler.[71] This translates to $10K to $11K/kg per year for five years and then almost $3K to $9.4K per year afterward.

Approximately 3,600 kg/yr of mercury are used for amalgam restoration by the dental sector in the Watershed.[72] For the entire sector, this translates to a cost that ranges from $2.6M to $3.8M[73] per year or approximately $734/kg to $1,057/kg of mercury. Each dentist spends from $336 to $408 per year on amalgam material containing mercury.[74] When charges for purchasing the mercury amalgam per year are added to the control option ($10M–$11M/yr), annual costs increase to $12.6M to 14.8M[75] per year for 5 years and then $5.6M to $13.2M/yr for each subsequent year; or $10.7K to $12K/kg per year for the initial 5 years and then $3.7K to $10.5K/kg per year afterward.

The cost of recycling solid waste amalgam is not directly tied to preventing water discharges, but should be included when providing an overall picture of cost. Each dentist would spend approximately $120/yr if recycling of solid waste occurred three times annually. Recycling would increase costs to approximately $13.3M to $15.6M/yr initially and then more than $6.3M to $14M/yr thereafter. The cost of recycling translates to an increase of $220/kg to $261/kg, for a total cost of $10.9K/kg to $12.3K/kg for full compliance by the sector (every dentist recycling) initially, and then $3.9K/kg to $10.7K/kg each year afterward. For each dentist, the overall cost of full compliance when using mercury amalgam, recycling, and separator filters would be approximately $1,775/yr for five years, and then $880/yr for each subsequent year.[76]

Alternatively, certain vendors offer full-service plans in which they retain ownership of the equipment and assume all associated liabilities. They waive the cost of the system when dentists sign up for a full-service package, which includes replacement and disposal of used filters, at an average rate of $1,200 per year ($11M, or $10.9K/kg, for

71. The amortization schedule employs an interest rate of 7% and constant payment over 5 years. The interest rate is an average and may vary according to each institution's credit rating, collateral, amount, and purpose of the loan, as well as payback terms and the lending institution's policies. Given the amounts projected here, a medium payback plan of 5 years was chosen. The same assumptions are made for the rest of the calculations throughout this section, except where POTWs are involved for reasons described earlier.

72. For calculations, refer to Appendix 6.2. The dental sector uses about 3,600 kg/yr of mercury, of which half is placed in amalgams. In addition, old amalgams containing about 2,400 kg/yr of mercury are removed. The Hg is either captured or released to different media.

73. Total cost of using mercury dental amalgam material in the watershed ranges from $2,643,648 to $3,806,314 per year.

74. On average, a dentist uses between 672 and 816 amalgams per year. Amalgam capsules (which include between 300 and 700 mg/capsule) range in size and price, but on average, cost about $0.51 each. Thus, the annual cost to the dentist is calculated by multiplying $0.51 times 672 and 816, which equals $342 and $416, or an average of $380/yr. From Henry Schein Alloys catalogue and http://www.sullivanschein.coml; also Dentsply-Caulk and Kerr supply catalogues.

75. With this option dentists are responsible for associated liabilities from managing hazardous materials on equipment they own.

76. Estimate assumes same number of amalgams placed per year. Refer to Appendix 6.2 for calculations.

TABLE 7. Dental Sector—Cost of Different Options[a]

	Overall Cost for Region per year for first 5 yrs	Hg Used or Treated (kg/yr)	Cost/kg of Hg at Source per Year
USE OF HG AMALGAM, RECYCLING AND CONTROL TECHNOLOGY			
Cost of amalgam materials	\$2.6M–\$3.8M	3,600 kg	\$734–\$1,057/kg
Comprehensive recycling of solid waste (removal and restorations)	\$659K–\$782K	3,000 kg	\$220–\$261/kg
Filter systems to prevent water discharges (removal and restorations)	\$10M–\$11M	1,000 kg	\$10K–\$11K/kg
TOTAL	**\$13.3M–\$15.6M**	**TOTAL**	**\$11K/kg–\$12.3K/kg**
PRODUCT SUBSTITUTION[b]			
Cost of composite materials	\$12M–\$17.5M	3,600 kg	\$3,378/kg–\$4,864/kg
Comprehensive recycling of solid waste (removal only)	\$659K–\$782K	2,100 kg	\$314–\$372/kg
Filter systems to prevent water discharges (removal only)	\$10M–\$11M	700 kg	\$14.3K–\$15.7K/kg
TOTAL	**\$22.8M–\$29.3M**	**TOTAL**	**\$18K/kg–\$20.9K/kg**

a Calculations based only on dentists currently using mercury in the Watershed.

b Removal of old mercury amalgams would still require recycling and filtering systems.

the sector in the watershed).[77] (The annual fee increases to approximately \$1,500 per year when including recycling of all other solid waste containing mercury.) The overall cost to the sector for the full service is approximately \$15.5M per year, or \$12.3K/kg, if one adds the cost of dental amalgam material and recycling.

The cost-effectiveness of pollution prevention measures becomes apparent when the dental sector's internal costs must be compared with those associated with recovering mercury after it is released to wastewater. If POTWs had to install metallic reduction and ionic exchange technology to prevent mercury effluents to the Harbor contributed by the dental sector, the annual cost would be \$500M for 10 years and \$282M per year thereafter (or \$1M/kg initially and then \$575K/kg each year afterward). This compares with dental sector outlays of between \$13.3M and \$15.6M/yr for 5 years and then \$6.2M to \$14M per year beyond that period. Moreover, whereas the cost to the POTWs is only to capture mercury in wastewater, the cost to the dental sector would be to prevent all mercury discharges, including those to solid waste as well as wastewater. Thus, from both societal and economic perspectives, it makes more sense to prevent Hg discharges at their point of generation–the dental offices.

Nevertheless, at least one study suggests that implementation of P2 and management practices at dental offices are difficult. The study, conducted in Seattle, suggests that only 2.5% of dentists in the study area may be using separator filtering systems after more than 5 years of a voluntary program that was instituted to prevent mercury from being discharged by dental facilities. Nationwide, this proportion is even lower, with fewer than 1,000 of the 110,000 dental practices utilizing separator filters.[78]

77. This does not include a one-time installation fee of approximately \$200/filter system (which may serve up to six dental chairs). Information on these services was provided by DRNA, NY.

78. Hazardous Waste Management Program, *Management of Hazardous Dental Wastes in King County,* 1991–2000; Gail Savina, King County Hazardous waste (May 2002); Marc Sussman, DRNA, personal communication (March 2002).

Possible administrative and technological barriers to implementation include the following:

- Most dental facilities are considered small businesses, and the additional cost to install the filtering equipment may be burdensome. However, because the public sector could avoid steep capital investments by reducing mercury loads to POTWs, they could work with the dental sector to solve the obvious barrier of financing this alternative. For example, a group-purchasing program could be organized to reduce the initial capital investment by purchasing equipment in bulk. In addition, lower interest rates on loans to dentists to install the equipment could be negotiated by municipal or state agencies.
- In New York County and New York State, Dental Society representatives encourage recycling, but do not believe there is a problem with discharging mercury into the sewers.[79]
- Recent studies have questioned the effectiveness of the International Organization for Standardization (ISO) standard of addressing mercury removal from ISO-approved separators because the standard does not address the effectiveness of removal of the soluble portion of the mercury discharge. Testing conducted by the City of Toronto indicated that at least one type of separator filter did, indeed, capture 99% of the total mercury mass (solid and soluble). EPA's environmental testing verification will be finalized in Spring 2002.[80]

For substitution of mercury amalgams, mercury discharges from the dental sector could be reduced at the source by substituting non-amalgam alternatives (e.g., light-cured resin) for mercury amalgams. This option, however, would not completely eliminate all mercury discharges in the short run. Removal of old mercury amalgams during restoration would continue to be discharged to sewers, unless filtering systems were in place. Furthermore, concern over the durability, cost-effectiveness, and safety of current amalgam alternatives remains an issue.

Recognizing these shortcomings, it is still a worthwhile exercise to assess the cost differentials between mercury and composite amalgam (materials only). On average, they are $2.00 per one-surface restoration; $2.40 per two-surface restoration; and $2.60 per three-surface restoration, or an average of $2.33 each.[81] Nevertheless, it is likely that dentists would be able to pass this differential onto patients, who are charged an average of $70 for a onesurface restoration when using mercury amalgam and $130 for the composite resin. The charge differential decreases for two-surface fillings, with $130 for amalgam and $170 for the resin material.[82] Besides higher costs associated with the alternative materials themselves, the main reason for the higher rate charged is the increase in time needed to apply the composite resin and the unforgiving nature of the process. (Several dentists have mentioned that training, regular practice, and new, more pliable resins have reduced this time differential considerably.[83])

If all dentists using mercury amalgam in the Watershed area were to use composite material instead, the associated cost would range from $12M/yr to $17.5M/yr, or $3.3K–$4.8K per kilogram of amalgam replaced to perform the same number of restorations. Each dentist would spend approximately $1,500 to $1,900/yr in restoration materials instead of $300 to $400/yr for amalgams. Furthermore, because removal of old mercury amalgams

THE UTILITY OF LIFE CYCLE ANALYSES

The utility of life cycle analyses is particularly obvious in the dental and hospital sectors. Product purchasing decisions are based on supply and demand within these sectors; however, a life cycle analysis shows that costs could be reduced and the releases of mercury decreased if a larger view were considered. This holds true in other cases as well. At the household level, for instance, if sewer and trash collection bills were tied to releases, different decisions might be made at the grocery store. For example, if trash costs were associated with volume, the consumer might choose a product with recyclable packaging, even if it cost more to purchase than a non-recyclable brand.

79. These Societies cite estimates that mercury in amalgam does not break down for at least a millennium. No document was provided to support this claim. (Based on conversations with society representatives (who will remain unnamed) on May 18, 2001).
80. Marc Sussman (DRNA), personal communication, 11/19/01.
81. http://www.sullivanschein.com, and Dentsply-Caulk Dental catalog.
82. Average from phone survey of dentists and dental plan schedule.
83. Several dentists within the Watershed contributed this information but asked that their names not be published.

would continue to release mercury, charges for the filtering systems and recycling could not be avoided for at least 15 years. Thus, all dentists would spend an additional $660K to $782K/yr for recycling, and approximately $10M to $11M/yr for 5 years to filter mercury discharged from removed amalgams. This would lead to an overall cost for the sector of $22.8 M to $29.3 M/yr for 5 years and $15.8M to $27.7M/yr thereafter. This translates to an overall cost of between $18 K to $21 K/kg of avoided mercury per year initially, and then $8 K to 18.7 K/kg thereafter, for the dental sector in the Watershed.

At first glance, the cost for moving to composite resin (including implementing the necessary control options to capture and recycling amalgam that is removed in the process) might seem exorbitant ($22.2M-$29.3M/yr initially or $18-20.9K/kg/yr), especially when compared with the cost associated with the use of mercury amalgam ($2.6M to 3.8M/yr or $ 737 to $1,057/kg), even with full recycling and filter costs included ($13.3M to $15.6M/yr initially or $10.9K to 12.3K/kg). However, an analysis of the life cycle of mercury amalgam requires consideration of costs external to the dental sector. For example, the marginal cost per kilogram of mercury recaptured at POTWs after installing the technology to prevent and average of between 5% and 30% of mercury effluents would be more than $1M/kg Hg. In addition, controls to prevent emissions from incineration of POTW sludge would cost between $464/kg and $3,500/kg each year. Preventing Hg emissions from crematoria (which result from the cremation of amalgams still present) in the Watershed would cost between $98.6K and 102K/kg of mercury recaptured if selenium filter systems were installed at each of the 45 crematoria in the Watershed.[84] From a socioeconomic perspective then, when the last three estimates are taken into account, it makes sense to use non-mercury alternatives instead of mercury amalgams, install traps and filtration systems, and recycle for the next 15 years or while mercury amalgams are still being removed.

Besides cost, several other economic, administrative or technological barriers need to be overcome to make the use of non-mercury alternatives possible:

- Application of currently available alternatives is more expensive, though some of this cost could be reduced through more effective training which would shorten the time needed for application
- Limited coverage by insurance companies
- Concerns over the quality, durability, and safety of currently available alternatives (especially for repair of posterior teeth), which may or may not be improved by R&D advances resulting from increased demand[85]

Ongoing environmental concerns related to mercury releases from the dental sector warrant action, but the complexities revolving around current amalgam alternatives must be considered. Thus, an incremental approach is recommended, which looks toward first expanding the numbers of practitioners who use filtration systems and recycle, and then looks toward the eventual goal of substitution of mercury amalgam by safe, durable, and cost-effective alternatives.

P2 and Management Recommendations for Dental Facilities[86]

Implement a tiered approach that:

- Institutes filtration, collection, and recycling in the short term; and,
- Moves toward substitution of amalgams by safe, durable, and cost-effective alternatives in the long term

Strategies to Achieve the Recommended Approach:

- Educate current and future members of the dental health care profession, and other interested parties, about the importance of preventing mercury releases[87]
- Develop programs to install economically feasible technologies that filter, collect, and recycle, at the highest levels possible, mercury in contact and non-contact amalgam
- Encourage the creation of a centrally coordinated mercury collection program
- Encourage the development of safe, durable, and cost-effective amalgam alternatives beyond existing materials

84. See Appendix 6.3. Prices for the "amalgamator system" (selenium filter technology) were provided by Vermeuleu Deventer.
85. In terms of safety, there is concern about possible allergic reactions to current amalgam alternatives.
86. The recommendations, strategies, and delineation of which stakeholders share responsibility for implementation take into account mercury releases from the dental sector to both wastewater and solid waste. For the full discussion on flows to solid waste, see Section 3.2. Landfills—Dental Facilities.
87. This could be done in the form of meetings or literature that describes the environmental impact of dental facilities on the region and the steps they can take to avoid contamination from their offices.

- Engage educational institutions related to the dental health care sector to train present and future caregivers in the use of amalgam alternatives
- Encourage the collection of information on recycling levels to monitor success

SAVING MONEY WHILE REDUCING EXPOSURES

Hartford Hospital (CT) replaced all mercury sphygmomanometers in 1999 after a study showed that the hospital spent over $60K just to clean mercury spills during a 12-month period. The cost of replacing all mercury blood pressure equipment in 1999 was $80K.

—Hospitals for a Healthy Environment, "Mercury Waste Virtual Model Plan (2000)," p. 40, www.h2e-online.org

Sharing Responsibility for Implementation:

The strategies outlined above will likely require a combination of voluntary and regulatory activities. The key stakeholders to involve will be dental care providers, dental associations, educational institutions related to the dental health sector, POTWs, producers and distributors of amalgam and amalgam alternatives, insurance companies, the real estate sector, and federal, state, and local regulatory agencies.

Hospitals. The hospital sector contributes over 25% of the mercury reaching the wastewater stream in the Harbor. This mercury comes from a range of products including measuring devices and instrumentation, chemicals, specialized batteries, fluorescent lamps, and cleaning agents and solutions.[88] Dental clinics within hospitals also contribute to mercury waste. Of the 1,400 kg/yr of mercury disposed of by hospitals, about 700 kg are released to wastewater. Hospital laboratories contribute more than 600 kg of the mercury discharged. Options for dealing with laboratory discharges are treated separately, but costs are included here. Hospitals with dental clinics add approximately another 10 kg/yr of mercury discharging to wastewater. Again, the options to prevent mercury discharges from dental clinics are explained above, but costs associated with mercury discharges from hospital dental clinics are included below. In addition over 70 kg/yr of mercury is discharged to wastewater when thermometers and sphygmomanometers break and spill.

Product Substitution. There are two instruments that /account for 10% of the mercury released to wastewater from hospitals: thermometers and sphygmomanometers (blood pressure instruments). For each of these, non-mercury alternatives exist.

Thermometers: Costs associated with use of digital or electronic thermometers range from almost $994K/yr to $2.9M/yr for the first 5 years and $635K/yr to $1.9M/yr thereafter. By substituting with non-mercury thermometers, hospitals may accrue savings ranging from $2.2 to $37M per year. Cleaning mercury spills can be expensive, ranging from $400 to $3,000 per spill, depending on the size of the instrument, loss of use of space, and availability of on-site trained personnel and equipment. Costs for cleaning and treating approximately 8,500 broken thermometers, containing 0.7 grams of mercury each, range from $3.4 to $38.7M per year, or between $566K/kg and $6.5M/kg to recover each kilogram of mercury spilled. Once costs for spill clean-up are included, full costs associated with use of mercury thermometers range from $3.5M to $39M per year.

Sphygmomanometers (blood pressure monitors): Given a financial package with an interest rate of 7% over 5 years, the cost of using digital or electronic sphygmomanometers is between $3.2M and $6.1M for 5 years. No additional operating expenses are involved after equipment is paid for. Net savings for hospitals using alternative sphygmomanometers may be as high as $17.9M per year for the first 5 years, and then range from $2.1 to $26M for each year thereafter. Costs for cleaning between 3,700 and about 8,000 broken sphygmomanometers containing 356 kg of mercury range from $1.5M to almost $24M per year, or $4.2K/kg to $67K/kg of mercury spilled. Full costs associated with use of mercury sphygmomanometers range from $2.1M to $26M/yr. Because aneroid (non-liquid) blood pressure instruments are widely accepted, there are no obvious impediments to their adoption, except "sunk" capital in mercury units currently in operation. Hospitals tend to purchase the non-mercury aneroid models once mercury units break or become defective.

88. Fluorescent lamps in hospitals are discussed in the solid waste section of this paper and included in the industrial/commercial fluorescent lamp section in Appendix 6.2.

TABLE 8. Hospital Sector—Cost of Product Substitution

	Cost for Region per year	Hg Used or Replaced (kg)	Cost/kg of Hg (at the Source)
USE OF HG PRODUCTS			
Thermometers	$85K–$430K	60 kg	$1.4K–$7K/kg
Cleaning thermometer spills	$3.4M–38.7M	6 kg	$571–$6.5M/kg
Sphygmomanometers	$617K–$2M	7,700 kg	$80–$259/kg
Cleaning sphygmomanometers spills	$1.5M–$24M	356 kg	$4.2K-$67K/kg
PRODUCT SUBSTITUTION			
Thermometers (electronic)	$1.3M–$2.9M	60 kg	$21.6K–$48K/kg
Sphygmomanometers (aneroid)	$3.1M–$6.1M	7,700 kg	$402–792/kg

In short, hospitals actually could save money by replacing these devices with non-mercury units. However, some technological and administrative obstacles exist that prevent the widespread adoption of non-mercury thermometers. These include,

- Perceptions about performance of non-mercury thermometers when small variance in temperature readings is critical (e.g., at intensive care units, neonatal, burn, and trauma units). However, many hospitals[89] in other states have been mercury-free for many years without experiencing such problems. Training on how to use the digital or electronic thermometers to optimal levels may be needed.
- Hidden costs associated with cleaning mercury spills need to be taken into account to demonstrate cost savings. Purchasing departments should consult the risk management department when making purchasing determinations. An overall non-mercury purchasing policy could take care of this problem.

Dental Clinics in Hospitals: Available options have been discussed before in the dental section. Only the cost associated with such options are given here. The annual cost of using about 60kg of mercury amalgam by, between 140 to 145 hospital dental clinics[90] in the Watershed, ranges from $50.4K to $75K/yr, or between $840 and $1.2K/kg of mercury. When the cost for comprehensive recycling is added, the total cost increases to $117.6K–$166K/yr, or $2.3K–3.2K/kg.

Discharges to wastewater from hospital dental clinics, of approximately 10 kg/yr of mercury, can be prevented by use of filtration systems, at a cost ranging from $108.6K to $225K/yr for 5 years and then $80K to $165K/yr each subsequent year, or from $7K to $15K/kg initially and then $5K to $11K/kg of mercury managed per year. When costs for using dental amalgam and recycling are added, the total cost increases to $226K–392K/yr for 5 years and then $197K-332K/yr afterward. This translates to a cost/kg range of $9.6K to $18K/kg of mercury initially.

Alternatively, dental clinics would spend between $232K and $332K/yr ($3.9K-$5.9K/kg of Hg replaced) when using composite resin for amalgam restorations. However, this option would not prevent releases from old mercury amalgam removed during restoration. The combined cost of installing and operating a filtration system and recycling the removed amalgam would range from $407K to $649K/yr for the first 5 years and then $379K to 589K/yr each subsequent year. This translates to almost $21.3K to $40K/kg initially and then between $17.5K to $31.6K/kg per year afterward.

Laboratories in Hospitals: There are at least 435 laboratories in the 256 hospitals in the Watershed (most hospitals have more than one laboratory on site).[91] As detailed in the laboratory section of this paper, an account of specific mercury-containing products and associated costs could not be completed. Therefore, cost for product substitution has not been computed, although alternatives exist for many

89. http://www.h2e-online.org
90. http://www.hospitalselect.com
91. http//: www.hospitalselect.com

of the mercury products currently in use. Nevertheless, the overall regional flow has been calculated from national flows estimates

Several options exist to prevent mercury discharges to wastewater from laboratories, such as filtration systems as well as recapturing the contaminated solutions, which are then either recycled or treated for safe disposal at landfills. Filtration systems may be applied either at the end of clinical analyzers or at end of the hospital effluent pipe before it reaches the sewer system. Costs associated with installing and operating filters at the end of clinical analyzers range from $813K to $8.1M per year for 5 years and then $261K to $2.6M per year thereafter, depending on the number of analyzer units in each laboratory.[92] This translates to a cost of $1.3K-$13K/kg captured per year during the 5 five years and then approximately $400/kg - $4.2K/kg per year afterward. Another filtration option is to trap all discharges from the laboratory before these enter the sewer system. Costs for such "end-of-pipe" systems depend on the volume of discharges per laboratory and range from $30K to $500K per unit, or from $2.3M to $34M per year for 5 years for all hospital laboratories in the watershed, and then from $348K to $1M per year afterward. In terms of cost per kilogram of mercury recaptured, the range is from $3.7K/kg to $55K/kg initially and then $560/kg to $1.7K/kg each subsequent year.

EDUCATING HEALTH CARE PROFESSIONALS ABOUT P2 —A NATIONAL EFFORT

Hospitals for a Healthy Environment (H2E) is a joint project of the American Hospital Association, U.S. EPA, Health Care without Harm, and the American Nurses Association. State and local organizations have since joined the effort. H2E educates health care professionals about P2 opportunities in hospitals and health care systems through a variety of activities, including developing and disseminating best practices, case studies, and resource directories. H2E aims to virtually eliminate mercury-containing waste from hospital waste-streams by 2005, and also to reduce the overall volume of waste.

—*http://www.h2e-online.org*

Alternatively, all solutions can be recaptured and then recycled or treated for safe disposal. The cost for each laboratory to recycle its waste solutions is $1,800 per 55-gallon drum. Hospital laboratories in the Watershed vary in wastewater output, ranging from 9 to 273 drums of solution per year, at an estimated cost of $16K to $491K/yr per laboratory. For all hospital laboratories in the region, the cost ranges from $7.1M to $213.5M/yr, or from $11K/kg to $344/kg of mercury recycled. A less expensive alternative is recovering the solutions for treatment and then safe disposal at landfills, though this is not as preferable in terms of environmental considerations. When choosing this option, laboratories pay only $500 per drum (instead of $1,800 for recycling). The overall cost for all hospital laboratories when selecting this option ranges from $2M to $59M per year, or $3K/kg to $96K/kg of mercury recovered.

For specific recommendations for hospital dental facilities, refer to the relevant section above; for laboratories, see the upcoming section below.

P2 and Management Recommendations for Hospitals:

- Substitute non-mercury alternatives for mercury-containing products
- Prevent breakage of current mercury-containing products

Strategies to Achieve the Recommended Approaches:

- Encourage replacement of current mercury-containing products with available alternatives
- Implement a non-mercury purchasing policy for new products
- Publicize net savings from substitution
- Encourage proper maintenance of existing stock of mercury-containing devices to avoid spills until all units are replaced with non-mercury alternatives
- Disseminate best management practices regarding wastewater disposal

Sharing Responsibility for Implementation:

Many hospitals are already moving toward substitution of mercury-containing products with non-mercury alternatives. The key stakeholders to involve in broadening and extending these efforts are hospitals, doctors, nurses, and

92. Owen Boyd, SolmeteX Co., MA; personal communication. Each filter can serve up to three clinical analyzers. For calculation details refer to Appendix 6.3.

related associations, hospital administrative and maintenance employees, and federal, state, and local regulatory and lending agencies.

Laboratories. This sector contributes over 15% of all mercury reaching the Harbor and its watershed via wastewater. Instruments, chemicals, and reagents used in laboratories for tests, experiments, and in preservative solutions (including vaccines) contain mercury.[93] Mercury in solutions is used either as an active ingredient or as a preservative. It may also be present as a contaminant introduced during manufacturing of one of the ingredients.[94]

Non-mercury replacements have been identified for some of these chemicals. However, this information is not well known among laboratory practitioners. Other options are to prevent discharge of mercury to the sewer system by control technology or by recovery and recycling/treatment. Laboratories may sign pretreatment agreements with their local POTWs that issue permits for water discharges. All facilities are expected to prevent mercury discharges to wastewater; however, the rate of compliance has been assessed as extremely limited.[95] Therefore, potential savings from avoided costs for control technology or recycling due to product substitution are not taken into account. Increasing compliance rates would require stepped-up enforcement and credible penalty risks for discharging mercury. Laboratories that continue to use mercury solutions should be required to install mercury filtration/trapping systems at either the effluent of clinical analyzers, or "end-of-pipe" systems. Alternatively, another option is to recover all wastewater-containing mercury (as well as other contaminants) and send it for recycling or treatment.

The following options to prevent mercury discharges are evaluated below: (1) product substitution of mercury with non-mercury solutions and chemicals; (2) control technology to reduce mercury discharges; and (3) recycling or treatment of discharged wastewater.

Product Substitution. Approximately two-thirds of the mercury used in laboratories is contained in chemicals, fixatives, reagents, and stain solutions.[96] Alternatives exist for many of these solutions. For example, Zinc Formalin can replace B5 fixative,[97] which may contain as much as 72 grams of mercury per liter. Costs for alternative products are often higher than mercury ones (e.g. a 4-liter bottle of hematoxylin costs $91, whereas available non-mercury substitutes costs $113 and $145.)[98] However, costs associated with product substitution will drastically reduce the volume and cost to treat gallons of contaminated discharges.

A count of specific mercury products and quantities bought by laboratories was attempted but not achieved because of a lack of proper labeling of solutions. Laboratory technicians did not know whether a chemical or solution contained mercury, especially when using automated systems procedures that involve clinical analyzers. Similarly, material safety data sheets often do not list mercury (if formula is proprietary information or if there is less than 1% mercury content).

Therefore, an overall estimate of cost associated with purchasing mercury products in laboratories could not be accomplished. Nevertheless, there are some administrative barriers to product substitution worth mentioning.

- Lack of knowledge of available alternatives. This barrier could be easily remedied through education and distribution of materials listing current non-mercury alternatives.[99]
- Concerns over quality of tests. (This is already less of a problem as more hospitals and laboratories share information about non-mercury alternatives that they have adopted.) Associations representing the health care industry should be engaged in an educational campaign on the use of non-mercury products.
- Lack of control by laboratories of what chemicals and solutions are used in their clinical analyzers and other standardized procedures. Laboratory managers should be encouraged to ask for certificate of analysis reports from all vendors, listing concentrations of all solutions, and then request use of non-mercury products only.

93. John L. Sznopek and Thomas G. Goonan, "The Materials Flow of Mercury in the Economies of the United States and the World," *US Geological Survey Circular* 1197 (Washington, DC: US Department of the Interior and USGS, 2000).
94. Hospitals for a Healthy Environment, www.h2e-online.org.
95. Carl Plossl (Hazardous Waste Compliance Department, EPA Region 2), personal communication, 11/5/01.
96. Sznopek and Goonan, "The Materials Flow of Mercury in the Economies of the United States and the World."
97. Both solutions are used as fixatives. Wisconsin Department of Natural Resources, *Wisconsin Mercury Sourcebook,* draft (May 1997).
98. Environmental Working Group/The Tides Center, *Protecting by Degrees: What Hospitals Can Do to Reduce Mercury Pollution,* (May 1999), http://www.ewg.org. Also, Pollution Probe, *Mercury in the Health Care Sector: The Cost of Alternative Products* (Toronto: Pollution Probe, 1996).
99. For a list of products containing mercury and available alternatives including some prices, see www.h2e-online.org; or Pollution Probe, *Mercury in the Health Care Sector.*

Control Option. Discharges to wastewater from laboratories may be prevented by use of an "effluent management system" installed at the discharge point of clinical analyzers (one system can filter mercury effluent from up to three clinical analyzers). The cost for each system is as follows: one-time fee of $5,000 for equipment and $200 for installation charges. Cartridge replacement is $150 three times per year.[100] Laboratories may have as many as 30 clinical analyzers; therefore the total cost associated with the purchase and installation of this system ranges from $5,200 for one system to $52,000 for 10 systems per laboratory. The capital investment required for preventing 400 kg of mercury from being discharged by all 270 non-hospital laboratories in the Watershed would range from $1.4M to $14M. Provided a 5-year loan package at 7% interest was secured, payments would range from $342K to $3.4M per year, plus filter replacement annual fees in the range of $162K to $1.6M. The combined total cost ranges from $1.6M to $15.7M per year for 5 years and then $162K to $1.6M each year thereafter, or nearly $4K/kg to $39K/kg for each of 5 years and then $405/kg to $4K/kg per year afterward.

Alternatively, laboratories may install "end-of-pipe" management systems for the whole facility at a cost of $30K to $500K per system depending on volume and concentration of mercury discharged. For all 270 laboratories in the Watershed, the one-time installation fee would range from $8.1M to $135M. With a 5-year financing plan at 7% interest in place, plus operating expenses, the cost ranges from $2.2M to $33.5M/yr for five years ($5.5K/kg–$84K/kg), and then $216K to $648K ($540/kg–$1.6K/kg) each year beyond. Although control of mercury discharges from this sector by available technology is not internally cost-effective, costs are considerably lower than those that prevent mercury flowing from POTWs into the Harbor ($500M/yr or $1M/kg for 10 years and then $282M/yr or $627K/kg thereafter).

One drawback for both of these filter systems is that they are capable of capturing mercury, but not a variety of other contaminants released by laboratories. Therefore, while continuing to use mercury-containing solutions, a better option is to capture discharges and then recycle or treat them, as described below.

Recycling or treatment of discharged wastewater. This option requires that all discharged mercury solutions be stored in containers until picked up by companies authorized to manage hazardous material. Laboratories may choose from two options: recycling or treatment (which includes stabilization and disposal at authorized landfills). From an environmental perspective, treatment of discharged solutions is less optimal, albeit the less expensive of the two.

Containers to capture contaminated solutions are available in multiple standard sizes, ranging from 5 to 55 gallons, and prices vary accordingly. If recycled, a 5-gallon bucket of contaminated solution costs $450; if sent for treatment and then to a landfill, that same bucket of solution costs $125. A 55-gallon drum of contaminated solution would cost $1,800 to recycle and $500 to treat and then send to a landfill.[101] A typical hospital laboratory in the region discharges approximately 550 gallons of solution per year per clinical analyzer. Assuming a similar vol-

TABLE 9. Laboratories—Cost of Control and Management Options

	Cost per year	Hg Used or Replaced (kg)	Cost/kg of Hg Recovered (at laboratories)
USE OF CONTROL TECHNOLOGY			
(1) Filter system at end of clinical analyzer	$504K–$5M[a]	400 kg	$1.2K-$12.6K/kg
(2) Filter system at end-of-pipe of lab	$2.2M–$33.5M[b]	400 kg	$5.5K-$84K/kg
RECOVERY OF DISCHARGES			
(1) Recycling	$4.4M–$132.5M/yr	400 kg	$11K- $331/kg
(2) Treatment and safe disposal	$1.2M–$36.8M/yr	400 kg	$3K-$92K/kg

a Per year for 5 years, then %162K to $1.6M per year thereafter, or $405 to $4K/kg.

b Per year for 5 years, then $216K to $648K, or $540 to $1.6K/kg.

100. Owen Boyd (SolmeteX Co, MA), personal communication, Nov. 15, 2001.
101. Clean Harbor Recycling Co., personal communication, October 2001.

ume for each non-hospital laboratory, it would cost $16K to $491K per year per laboratory to recycle discharges, or approximately $4.5 to $136K per year to treat them. The costs to the whole sector would be approximately $4.4M to $132.5M per year ($11K to $331/kg per year) for recycling, or $1.2M to $36.8M per year ($3K to $92K/kg per year) for treatment of the wastewater.[102]

Presently, recovery and recycling rates are very low and few laboratories have filtering systems to trap mercury discharges.[103] However, there are some measures that can be taken.

P2 and Management Recommendations for Laboratories:

- Substitute non-mercury alternatives for mercury-containing products
- Prevent mercury discharges to sewers

Strategies to Achieve the Recommended Approaches:

- Use non-mercury chemicals and reagents whenever possible
- Implement a non-mercury purchasing policy (Consider tax incentives for use of non-mercury solutions (or very high prices for mercury-containing chemicals to discourage their use) to help change practices in the lab. Note that although prices for alternatives are higher, hospitals could accrue net savings by product substitution because costs for recycling mercury-contaminated wastewater will be drastically reduced.)
- Require better labeling
- Educate laboratory technicians and hospital administrators about non-mercury alternatives
- Install filter systems to reduce mercury discharge by 99% (costs for installing such systems, although high for this sector, are still lower when compared with costs for capturing mercury at POTWs.)
- Encourage cooperation between POTWs and the health care sector to limit mercury discharges (See above discussion under the dental facilities section. Such cooperation could resolve financial obstacles to implementation of this option and should be encouraged. Also, loan packages with low interest rates and either federal or state guarantees could reduce overall cost of financing the appropriate controls.)
- Capture all discharge solutions in a tank (not just those with mercury) and recycle or treat them (This is optimal from an environmental perspective. Reducing inputs to POTWs may require organization of a centrally coordinated collection program. This may solve two problems simultaneously. First, all laboratories would comply, and second, the cost for each laboratory would be reduced.)
- Encourage the collection of information on release levels to monitor success

Sharing Responsibility for Implementation:

Key stakeholders to involve in implementing the recommended strategies include laboratory technicians and administrators, POTWs, chemical producers, federal, state, and local regulatory agencies and lending institutions. Because many hospitals have laboratories, they too should be included.

Major Sources of Mercury Emissions to Air[104]

Combustion processes (internal combustion engines and furnaces) account for over half of total air emissions of mercury within the region (see Tables in Appendix 6.1). Maximum available control technology (MACT) that could significantly reduce these emissions is not currently utilized. Installing MACT at power-generating utilities, and industrial/commercial facilities would cost from $18.6K to $36K to prevent 1 kg of mercury from being released (Table 10). No economically feasible controls to reduce emissions from residential furnaces or from automobile internal combustion have been developed.

Emissions from incineration of medical waste or municipal solid waste are currently lower than just a few years ago because of installation of MACT.[105] Costs associated with these control technologies range from $464/kg to $3,500/kg of mercury recovered.[106] Installing MACT at EAFs to recover the mercury from switches inside vehi-

102. Personal communication with hospital representative who prefers to remain unnamed, November 2001.

103. Carl Plossl (EPA Region 2), personal communication, 11/5/01.

104. Note that combustion refers to the burning of fuels, whereas incineration refers to the burning of materials to reduce their volume or convert organic into inorganic material. See Section 2.2, "Emissions of Mercury to Air" for further detail.

105. The State of New Jersey has lowered emissions from its large municipal waste incinerators below the federal limit. The State of New York has been in the process of lowering emissions from incinerators since 1998 when the State Environmental Board approved more stringent requirements for medical waste incinerators, municipal waste combustor and municipal landfills. http://www.dec.state.ny.us/website/press/pressrel/98-106.html; and Mary Werner, personal communication, January 18, 2002.

106. U.S. EPA, *Mercury Study Report to Congress,* v. 8, part B, pp. B-3 to B-8.

TABLE 10. Cost of Primary Controls to Prevent Emissions of Mercury to Air[107]

Product/Sector[a]	Hg in Solid Waste Sent to Incinerators (kg/yr)[b]	Yearly Cost of MACT to Control Emissions to Air (range)
Incineration (cost of controls already in use by WTE, MWC, MWI: $464–$3,500 per kg of Hg captured)[106]		
Dental facilities	1000	$464,000–$3,500,000
Hospitals	200	$92,800–$700,000
Households—thermometers	100	$46,400–$350,000
Laboratories	50	$23,200–$175,000
Batteries	30	$13,920–$105,000
Fluorescent lamps	175	$81,200–$612,500
Switches—lighting	30	$13,920–$105,000
Thermostats	200	$92,800–$700,000
Incineration (cost of potential control: $98K—$102K/kg for first five years then $11K–$14K/yr)[c]		
Crematoria	25	$2,450,000–$2,550,000

Products	Hg Released to Air from EAFs without MACT (kg/yr)	Potential Annual Cost of MACT to Control EAF Emissions (range)
Incineration (cost of potential controls: $18.6K–$36K per kg of Hg captured)[d]		
Switches–auto	900	$16,740,000–$32,400,000

Sector	Hg Released to Air via Combustion without MACT (kg/yr)	Potential Annual Cost of MACT to Control EAF Emissions (range)[e]
Combustion Emissions (Cost of potential controls: $18.6K–$36K per kg of Hg captured)[d]		
Automobile combustion	150	N/A
Household: furnaces	150	N/A
Industrial/commercial furnaces	350	$6,510,000–$12,600,000
Utilities: furnaces	400	$7,440,000–$14,400,000

a These calculations are based on solid waste only. The figures in this column do not include the cost of trapping the mercury released during the combustion of sludge.

b See Appendix 6.1 for explanation of how these numbers were calculated. Approximately one-third of solid waste is sent to incinerators.

c To control mercury emissions from crematoria, the cost is $200K for each facility (45 in the Watershed) for the equipment plus $10/cremation with an average cremation rate of 1,000/yr per facility. Thus, total cost for the sector is $9,450,000/yr and $210,000 per facility. These costs are reported so no range is given.

d If activated carbon injection (ACI) in addition to baghouse filters were applied. Of the 900 kg/yr sent to EAF, only 300 kg are released to air. The remainder stays with the ash.

e Between 75% and 95% of emissions from furnaces burning oil and coal could be prevented with MACT (E. Brown, EPA Headquarters, personal communication, November 28, 2001).

107. These costs include capital recovery costs as well as operating and maintenance costs. As the capital investment is paid off, the costs will be lower. In general, the low value of the range represents maintenance and operating costs, whereas the high value includes capital expenditure.

cles that are smelted at end of life would cost as much as it does to recover mercury from combustion at utilities ($18.6K to $36K/kg). However, substitution to ball-bearing switches in automobiles would prevent that expense. No controls are in place at crematoria. Controls for this sector would require $2.5M –$2.6M/yr for 10 years and then approximately $270K to 360K/yr thereafter, or about $99K to 102K/kg of mercury recovered. There is no way to capture mercury released through volatilization, except by preventing its release in the first place through better management and/or substitution by non-mercury alternatives.

Reviewing the sectors that contribute mercury to air leads to the following priorities for action:

- Automotive and appliance switches (via EAFs)
- Fluorescent lamps (volatilization when broken)
- Coal/oil Furnaces (industrial, commercial, household combustion)

Automobile and Appliance Switches. Automobiles and other vehicles release mercury to the environment in two different ways. First, mercury is released via internal combustion of fuel (mercury is a trace element in gasoline). Second, many vehicles contain mercury switches in ornamental or "under-the-hood" lights, in HID lamps, and in antilock brake systems (especially SUVs). A considerable amount of mercury in switches can be released when vehicles (and to a lesser extent, appliances) are disposed, shredded, and then sent to electric arc furnaces for smelting.

Internal Combustion. This process contributes approximately 150 kg to total mercury emissions to air. No controls are currently available to capture mercury from vehicle exhaust. The best solution is source reduction, which could be achieved by increasing fuel efficiency in vehicles, increasing the use of "hybrid" cars, as well as increasing the use of public transportation. Investments in transportation alternatives (including waterways) coupled with public awareness campaigns about available alternatives and related benefits are needed to decrease reliance on traditional modes of transportation.

Automotive and appliance switches. Switches and related items contribute approximately 10% of mercury releases to the watershed as a result of the steps taken at an automobile's end of life. Automobiles, other vehicles, and appliances are shredded, and the processed scrap metal then is sold to steel mills where it is smelted in EAFs. Approximately 900 kg of mercury in switches is currently discarded each year in the Watershed when cars are disposed at end of life. As a result of the scrapping and smelting process, it is estimated that approximately 300 kg/yr of the mercury in switches is released to air.[108] MACT is not in place at EAFs. Costs for MACT ($18.6K/kg to $36K/kg recovered) are given in Table 10 and could be avoided by product substitution, comprehensive replacement, or recovering switches before cars are shredded.

The total annual cost to remove between 744K and 1.1M switches with an average of 900 kg of mercury at end of life of vehicles would amount to $457K to $604K/yr or approximately $507 to $671/kg of mercury recovered.[109] Replacing about 7 million mercury switches in all cars registered in the Watershed would require a one-time investment of between $8.8M and $13.4M to recover an average of 9,700 kg of mercury in switches replaced, or $905-$1380/kg of mercury recovered. This cost could be easily distributed with very little administrative difficulty, if replacement of current mercury switches becomes part of the annual inspection process. Vehicles in which no mercury switches are found, or in which they have been removed, could have a sticker placed on them or some other type of certification produced so at each vehicle's end-of-life, it would be readily apparent that no more mercury switches are present.

For new automobiles, the better option is still product substitution. A 1997 study indicated that the Chrysler Corporation estimated it would save $40,000 in costs by using a rolling ball switch instead of mercury switches, mostly from reduced administrative costs sustained for compliance reports related to hazardous materials management, as well as reduced liabilities.[110] (No information was provided on the number of cars or switches accounting for this savings). Indeed, at the end of the 2002 model year (mid-August 2002), mercury switches will be entirely phased out of all automobiles and light trucks.

In summary, preventing the release of 300 kg/yr of mercury (of the 900 kg) from automobile switches incinerated at EAFs would cost $18.6K/kg to $36K/kg each year if controls were installed. This compares to only $507-$671/kg per year if the switches were removed from disposed cars before incineration at the EAF. If all cars within the Watershed were to have the switches replaced

108. Approximately 30% of the mercury is released to air. Nickolas Themelis (Columbia University), personal communication.

109. See Appendix 6.3 for the calculations behind these numbers.

110. U.S. EPA, *Mercury Study Report to Congress,* v. 7, pp. 5–9. Also, Ana Smith and Kathy Gran (Daimler-Chrysler), personal communication.

(i.e., automobiles still in use), the cost would rise to $905 to $1380/kg each year, still substantially lower than the cost to remove mercury at the EAF endpoint.

Appliance manufacturers for some time have been utilizing non-mercury switches in new appliances (with the exception of gas pilot-light ranges, for which no safe alternatives currently exist). For vehicles, whereas removing mercury switches from ornamental lights may take 30 seconds each, removing them from antilock brake systems or home appliances is time onerous and may take as much as a half hour, making the associated labor costs exorbitant. Thus, removing antilock brake systems (ABS) from cars will represent a large burden for those who have to carry out the task. Car dismantler representatives remain concerned that if regulations are imposed mandating removal of all switches from automobiles (including ABS brakes) and appliances at end of life, they will have to absorb this additional cost, to the detriment of their businesses.

Thus, in addition to making replacement of mercury switches in ornamental lights part of the annual inspection process, some type of cost sharing scheme, combined with research into safe non-mercury alternatives for ABS brakes, might make substitution not only technologically possible at some point in the future, but more palatable from an economic perspective as well.

P2 and Management Recommendations for Vehicle and Appliance Switches:

- Recycle/retire mercury switches already present in automobiles, light trucks, and appliances
- Develop safe non-mercury alternatives for switches utilized in gas pilot-light ranges
- Develop an understanding of the uses of mercury switches in heavy-duty trucks and buses, the amount of mercury present, and the availability and cost-effectiveness of non-mercury alternatives

Strategies to Achieve the Recommended Approaches:

- Educate consumers, scrap metal recyclers, and mechanics about the possibility and importance of replacing and retiring mercury switches
- Create a collection program for the removed mercury switches
- Support incorporating the removal of mercury switches already present in automobiles and light trucks into annual inspections, combined with a labeling system to record whether or not they have been removed
- Require removal of remaining mercury switches in automobiles and light trucks at end of life
- Support research on developing safe non-mercury alternatives for switches in gas pilot-light ranges
- Support research on mercury switches in heavy-duty trucks and buses

Sharing Responsibility for Implementation:

Many automobile and home appliance manufacturers are already complying voluntarily to substitute non-mercury switches in their new products, without detriment to quality or cost. Key stakeholders to involve in accelerating and extending this process to switches already in the market are automobile manufacturers, appliance manufacturers, switch manufacturers, the Steel Manufacturers Association, scrap metal recyclers, appropriate unions, and federal, state, and local regulatory agencies.

Fluorescent Lamps. Mercury emissions from fluorescent lamps come from volatilization when lamps are broken, and from incineration of discarded lamps. Fluorescent lamps are used in commercial, industrial, and residential settings; compact fluorescents are used mostly by the household sector. Approximately 38 million fluorescent lamps are sold in the Watershed region each year, including more than 33 million fluorescent tubes, 3 million compact fluorescents, and almost 2 million high-intensity discharge (HID) lamps.[111]

Although fluorescent lamps contain mercury, they are preferred to incandescent lamps because of the energy savings they provide. The cost associated with the purchase of more than 38 million fluorescent lamps ranges from $153M to $968M per year, rendering net savings of over $1B per year[112] when compared to using incandescent lamps, which may consume as much as three times more electricity. The amount of mercury in spent lamps currently being disposed in the region (700 kg/yr)[113] is higher than the amount used in new lamps (650 kg/yr) because mercury usage per fluorescent lamp has been reduced drastically over the last 15 years. (Some fluorescent lamps now have mercury levels below the current regulatory limit.) However, complete substitution has not been achieved. Thus, to prevent these releases, con-

111. See Appendix 6.2 for reference.

112. See Appendix 6.3

113. This figure does not include of mercury in recycled lamps (20% of the total).

sumers must recycle all spent lamps. Two methods are currently used to manage spent lamps: (1) sending lamps to recycling facilities; and/or (2) in-house crushing machines (for large quantity generators only). However, there are concerns that crushing machines do not prevent releases of mercury from volatilization, and because these machines generally are used in enclosed facilities (basements or storage areas), the risk of mercury exposure to workers is increased. This method also results in drums of crushed material containing levels of mercury high enough to carry a designation of hazardous material, thereby increasing costs and difficulties of transport and disposal. Therefore, crushing is not recommended.

The EPA recommends lamp recycling, which entails re-boxing spent lamps for safe transport during delivery to a recycling facility. Until January 2000, recycling required hiring a hazardous waste hauler and time-consuming paperwork. Since then the EPA has approved the Universal Waste Rule to encourage recycling, especially among industries, institutions, and commercial organizations. Facility managers must contact the local recycling companies and discuss intended disposal procedures before implementing a recycling program. If all consumers of fluorescent lamps were to recycle all spent lamps in the region (containing 700 kg of mercury) they would spend approximately \$24M/yr, or almost \$34.6K/kg of mercury recycled. However, this cost is offset by current energy savings of more than \$1B/yr. Recycling fluorescent lamps has become easier under current regulations, but these have yet to improve the low rates of recycling in the Watershed.

P2 and Management Recommendation for Fluorescent Lamps:

- Comprehensive recycling
- Develop more effective management technologies

Strategies to Achieve the Recommended Approach:

Commercial,[114] Industrial, and Institutional Facilities Generating 30 or More Lamps Each Month:[115]

- Educate users on regulatory requirements
- Require maintenance of proper documentation and record keeping of recycling
- Strengthen monitoring and enforcement procedures

Small Businesses[116] and Households Generating Less Than 30 Lamps Each Month:

- Educate consumers on the proper handling of fluorescent lamps
- Encourage the creation of take-back programs
- Create centrally coordinated collection programs
- Develop better ways to streamline and rationalize current recycling processes
- Support research to find lower cost methods for dealing with lamps, including consideration of the costs and benefits related to safe and effective sequestration of mercury in lamps

Sharing Responsibility for Implementation

For commercial, industrial, and institutional facilities, the key stakeholders will include the lamp manufacturers,

COAL CLEANING AND MERCURY: A LITTLE-KNOWN STORY

While many people are aware that different sources of coal have varying amounts of mercury, most do not know that the process of cleaning coal before its arrival at a utility furnace releases significant amounts of mercury into the environment.

Thirteen states (AL, IL, IN, KS, KY, MD, MO, OH, OK, PA, UT, VA, WV) account for half of all U.S. coal production. Before shipping the coal, these states clean greater than 75% of it to remove sulfur and noncombustible ash. Almost 9,100 kg (or one-fifth) of the mercury is removed as a result of this process, with much of the mercury ending up in retention ponds where it is released into the atmosphere.

—*Environmental Working Group/Clean Air Network/NRDC, Mercury Falling: An Analysis of Mercury Pollution from Coal-Burning Power Plants (Washington, DC: EWG, Nov. 1999), p. 9.*

114. The commercial sector is the least represented in terms of current recycling. Thus, the Consortium recommends focusing on commercial businesses.
115. 30 lamps per month is a figure informally accepted by NEMA and lamp recyclers. It represents the number of lamps in 1 box of a particular type of fluorescent lamp and has thus served as a convenient cut-off point for distinguishing among those who would be required to recycle and those who would be encouraged but not required.
116. The Consortium recommends emphasizing recycling among small businesses, which generate more lamps for recycling than an average household.

lamp recyclers, energy service companies (ESCOs), the various facilities utilizing the lamps, distributors, appropriate trade unions and associations, and federal and state regulatory agencies.

For small businesses and households, key stakeholders to involve in implementation will be lamp manufacturers, lamp recyclers, utilities, appropriate trade unions and associations, hardware stores, and electrical supply stores and other supply outlets, along with individual homeowners and small businesses, and state, local regulatory agencies and governments as necessary.

Utility, Industrial/Commercial, and Household Furnaces. Within the region, about 47% of the total mercury emissions are associated with combustion of fossil fuels results from electric utility, industrial, commercial, and household furnaces. (Automobiles generate another 8%.) Given their size and frequency of operation, coal and heavy-oil-fired electric utility furnaces are of particular concern. When discussing anything related to utilities in the Watershed, one must be careful to distinguish between generators that produce electricity, and utilities that only distribute it; the latter purchase electricity from a national power pool.[117] Therefore, any recommendations made for this sector should take into account the potential that controls or substitution of fuels in this region could make local power plants less competitive than others nationally. Thus, recommendations for this sector should extend nationally, unless the reductions sought are specifically regional in nature.

Fuel Substitution. By switching to cleaner fuels, power generators and commercial furnaces could drastically reduce air emissions of mercury. Natural gas is an attractive option because its use results in much lower nitrogen oxide emissions and no sulfur dioxide emissions. However, cost is a critical factor here. The cost for using coal fluctuates, but may be approximately 30% less than the cost for using gas.[118] Moreover, it is expected that the price of gas will increase because reserves are more limited than those for coal. Subsidy reform could encourage fuel switching if financial assistance for dirty fuels were no longer in place. Nevertheless, power generators are reluctant to rely on only one type of fuel, and prefer to use a fuel mix, in part to avoid price spikes and supply interruptions.[119]

Control Technology. The low relative cost of coal and its abundance within the borders of the United States make it likely that coal will maintain a significant market share as a fuel for the production of steam to produce electricity. Thus, there needs to be greater emphasis on developing suitable emission control technologies. There are several control options to reduce emissions, including use of powdered activated carbon injection (PAC) in conjunction with spray cooler and fabric filter systems, as well as wet scrubbers and coal washing. In 1997 the U.S. EPA estimated that the cost for installing and operating PAC systems ranged from $31,000 to $60,000[120] to recover 1 kg of mercury. Since then, this estimate has been scaled down by approximately 40% when using a composite sorbent (lime and carbon instead of just PAC) but optimal controls are still being evaluated (current cost estimates per kilogram of mercury captured range from $18,600 to $36,000, which in the Watershed region translates to $7.4M to $14.4M for utility furnaces and $6.5M to $12.6M for industrial/commercial furnaces).[121] It is likely that actual implementation would decrease the cost of this technology even further.

Energy Efficiency. An important interrelated issue has to do with the growth of electricity demand and associated emissions. In industrialized countries, residential electricity has grown by 23% since 1990.[122] The U.S. Department of Energy reports that growth in electricity demand in the next twenty years will require building more than 1,000 new power plants nationwide[123] and New Jersey's independent

117. As a practical matter, there is a perpetual flow of electricity across states, regions, and even between the United States and Canada as independent generation companies and wholesale customers buy and sell power for delivery to retail customers. Environmental regulations that add production costs to a subset of power plants within a region or a set of interconnected regions can result in shifting generation to power plants outside the sphere of regulation, awarding competitive advantages to companies and states that successfully resist such regulation.

118. $0.30 per hundred cubic feet of gas; Martha Bell (Association for Energy Affordability, NYC), personal communication, 11/20/01.

119. After deregulation, regional power generators compete with extraregional ones because utilities can purchase from a national electricity grid. Russell Furnari (PSEG), personal communication.

120. U.S. EPA, *Mercury Study Report to Congress,* v. 7. The higher estimate includes the cost for a spray cooler and fabric filter system required as part of MACT.

121. Costs have decreased for other reasons as well. First, existing controls to prevent releases of sulfur dioxide and nitrogen oxide (according to current regulation) have been found to capture up to one-third of the mercury released. Second, the capital cost of installing the PAC controls has decreased. Memorandum, September 30, 2000. http://www.epa.gov/mercury.

122. Institute for Sustainable Development, "Policies and Measures to Reduce Greenhouse Gas Emissions: Findings by the International Energy Agency," *Earth Negotiations Bulletin* 1 (NY: IISD, October 2001). The ENB is published by the International Institute for Sustainable Development (IISD) in cooperation with the UNFCCC Secretariat. http://www.iisd.ca/linkages/climate/cop7/enbots.

123. http://www.pseg.com/investor/annual/growing_dom.html.

system operator has approved construction of approximately 40 new generation plants in the Pennsylvania, New Jersey and Maryland Interconnection.[124]

Implementing a registry of current emissions and a cap might prompt new power plants to install state-of-the-art technology to prevent new mercury emissions. Demand-side management, energy conservation, and cogeneration may prevent the need to build new power plants. Electricity demand may be reduced by establishing minimum energy performance standards (MEPS) for home appliances and other energy intensive devices, appropriate labeling, and building codes. Other measures to reduce demand include reducing "light pollution." Greater than 30% of the electricity generated for outdoor illumination is wasted when misdirected into the sky or beyond the area that requires illumination. It has been estimated that nationwide this costs approximately $4.5M per year.[125]

Finally, mercury emissions from fossil fuel combustion by the household sector are linked to heating generation. Costs for controls to prevent mercury emissions from each household's furnace have not been estimated and would be prohibitive. Substitution to cleaner or renewable sources of energy (gas, solar) would reduce mercury emissions, but in general oil is less expensive than gas. Nevertheless, households have clear incentives to reduce their overall heating demand. Households would benefit from ongoing weatherization programs to prevent heat from escaping buildings.[126]

In December 2000, the U.S. EPA announced its decision to regulate mercury and other air toxics emitted from oil and coal-fired power plants. It is understood that the agency will propose sunsetting mercury emissions, with industry flexibility as to how to meet the set limits, through either fuel substitution or controls. This process should be supported, keeping in mind the need to ensure that the companies in the Watershed remain competitive nationally. All measures leading to energy conservation to reduce continuing growth of energy demand and associated emissions should be promoted.

Administrative barriers to implementation include:

- Requirements to reduce mercury emissions by controls or fuel substitution may drive up electricity rates. A recent article indicates that utilities predict rates will rise as much as 25% if forced to reduce mercury emissions. However, this estimate is based on outdated numbers and thus overestimates actual costs.[127] As noted above, the U.S. EPA has been conducting full-cost analysis of the energy market, including the impact of using MACT to reduce mercury emissions.
- In general, demand-side management programs were subsidized by utilities until deregulation took place. After deregulation, these programs have been taken over by state agencies and need to be properly subsidized and publicized.

P2 and Management Recommendations for Furnaces:

- Reduce emissions
- Substitute non-mercury-containing fuels

Strategies to Achieve the Recommended Approaches:

- Use MACT technologies for commercial and industrial furnaces
- Promote energy conservation for all consumers
- Encourage the use of cleaner fuels

Sharing Responsibility for Implementation:

Much has been done to move toward reducing emissions and substituting cleaner fuels, but more remains to be done. The key stakeholders to involve in implementing the above recommendations are utilities (both generators and suppliers), producers of MACTs, federal regulatory agencies, and consumers of fuel.

Landfills: Solid Waste Management

Implementation of the pollution prevention strategies described earlier for the three major contributors of mercury to wastewater (dental facilities, hospitals, and laboratories) also would decrease significantly the amount of mercury going to landfills and monofills. Many of the

124. Ibid. New Jersey's independent system operator—the Pennsylvania, New Jersey, and Maryland Interconnection (PJM) has approved construction of some 40 new generation plants that would add approximately 25% more electric capacity to the region over the next several years. http://www.pseg.com/investor/annual/growing_dom.html; also Michael Aucott, personal communication, 11/26/01.
125. http://www.njaa.org/light.html. Several dozen municipalities in New York State, and at least one township in New Jersey have some form of external light regulations. Sen. Mike Balboni has sponsored a NY Senate bill. The legislation, also sponsored by Assemblyman Pete Grannis (D-Manhattan), would require state agencies to install street lights that focus their illumination downward as replacements are needed, require the state Department of Environmental Conservation to designate "dark areas" to protect astronomy and ecological habitats and outlaw "light trespass" where outdoor lighting from one site intrudes on another's property.
126. Such as weather stripping and double-glazed windows, as well as increasing the efficiency of furnaces by proper maintenance.
127. Lee Hawkins Jr., "Wisconsin Utilities Criticize Plan to Reduce Mercury Emissions," *Milwaukee Journal Sentinel* (9/4/01).

other sources of mercury to landfills and monofills, including thermostats, fluorescent lamps, switches, and thermometers present straightforward and proven strategies for reduction that also should be considered. All of these products can be recycled and in some cases, national, state or local programs are already in place (see discussion of individual products below). An important finding of the public opinion survey, conducted as part of this project, is that the Watershed population is already conscientious about recycling. In fact, almost 90% of respondents to the survey said they recycle always or often, compared with only 68% of national respondents. Thus, the foundation for these P2 strategies is already in place within this region.

Various mercury-containing products are disposed in the pathway that leads to landfills. The main mercury-bearing products sent to all-purpose landfills are fluorescent lamps, fever thermometers, batteries, car switches, small household appliances with mercury switches, and other household waste. Noninfectious solid waste (black bag) discharged by the medical and health care sector, including laboratories and veterinaries, also may contain mercury products (broken thermometers, sphygmomanometers, and other instrumentation), which are sent to landfills. In addition, demolition debris sent to landfills contains thermostats, lighting switches, barometers, sprinkler systems, and other items containing mercury.

The main alternatives to prevent mercury from being sent to landfills are product substitution, which completely eliminates mercury at the source, and comprehensive recycling to reduce environmental releases. Recycling of mercury will prevent uncontrolled sequestration of mercury in landfills, but mercury would likely still be sent to specialized monofills because the supply at present is much greater than demand. The major sectors and products contributing mercury to solid waste in the region are: the dental sector, hospitals, car switches, and thermostats. Several of these already have been discussed above, especially when substitution is the preferred option (e.g., thermometers and sphygmomanometers in hospitals and car switches). Below, the focus is on sectors or products that can still benefit from comprehensive recycling.

Dental Facilities. Currently, dentists are required to recycle mercury waste from amalgam use by collecting contact and non-contact amalgam waste and sending it to a recycler. They are not required to report releases because they are conditionally exempted as small quantity generators. Actual rates of recycling among dentists are estimated to be quite low.[128] Costs for recycling mercury-containing dental waste could be kept to a minimum if scrap mercury and any amount recovered from chair-side traps were segregated from other solid waste. Sending a 5-lb. container directly to the recycling facility, for example, costs $25, plus $2 for each additional pound of "contact amalgam." In addition, a $15 charge per container is assessed for shipping by common carrier.[129] It is estimated that three shipments per year may be sufficient to recycle the mercury recovered by each dental office. Recycling companies pay the dentists for non-contact amalgam when more than 3 lbs is sent. The payment rate fluctuates with the price of silver (amalgam is composed of 30–40% silver). Substitution of mercury amalgam with non-amalgam alternatives would considerably reduce the amount of mercury ending up at landfills, but as discussed in the section on dental facilities and wastewater, this is a long-term solution.

The dental sector in the Watershed generates 3,000 kg or mercury as solid waste each year. If not recycled, one-third of the solid waste is incinerated and two-thirds are sent to landfills. The associated recycling costs of the total

ACTION AT THE LOCAL LEVEL: INDUSTRY–GOVERNMENT PARTNERSHIPS AT WORK

Westchester County (NY) Executive, Andrew J. Spano, recently signed a law banning the sale of Hg thermometers and the use and sale of Hg manometers throughout the county. The law went into effect on March 31, 2002. Residents of the county have been encouraged to turn in their Hg thermometers for free digital replacements during scheduled countywide household chemical clean-up days. These "Hg thermometer roundups" are part of a joint effort with Wheelabrator Westchester LP, the company that operates the county's incinerator.

— *http://www.co.westchester.ny.us/ currentnews/ mercury.htm*

128. Hazardous Waste Management Program, Management of Hazardous Wastes in Kings County, 1991–2000.
129. Solid waste containing "contact amalgam" (which has been in the patient's mouth) needs to be recycled or sent to a secured chemical landfill. Non-contact amalgam may be recycled. However, because dentists pay for delivery ($15 per container) and because production of non-contact amalgam per year within one dental office is not enough to fill a container over 3 lbs, this type of waste is usually disposed along with the contact amalgam.

mercury generated as solid waste by more than 11,200 dentists, in about 7,850 dental offices, would be $660K-$782K/yr, or $220-$261/kg of Hg in amalgam recovered, and even less if all dentist sharing an office would share recycling costs.[130] Remarkably, once recycled, the same 3,000 kg of mercury may be sold for as little as $4.2/kg[131] for a sector total of $11.7K.

For P2 and management recommendations, see the earlier section on dental facilities.

Thermostats. These devices are temperature regulators used in heating and ventilation systems. Most non-programmable thermostats contain mercury switches with approximately 2 to 3 grams per switch. Non-mercury thermostats (electric and digital) are available and often are comparable in cost to the mercury units. Therefore, when installing new systems, utilizing digital or electronic programmable thermostats is possible and, when used properly, are cost-effective.[132] It is estimated that approximately 152,000 mercury thermostats are discarded every year in the Watershed region, and it is likely that most of these units are disposed as either regular trash or demolition debris.[133]

In recent years, thermostat manufacturers such as Honeywell, General Electric, and White-Rodgers have established a private corporation, the Thermostat Recycling Corporation (TRC), to remove mercury from the thermostats and recycle it. This program recycles mercury-switch thermostats in the 48 mainland states of the United States.[134] Distributors can sign on for an initial fee of $15 to cover the cost of the container. The cost of recycling is absorbed by TRC. In 2000, this corporation recycled approximately 1500 mercury-switch thermostats in the Watershed region, and approximately 935 units in the first half of 2001. This represents only a minute fraction of all thermostats discarded at end-of-life in the region.

P2 and Management Recommendations for Mercury-Switch Thermostats:

- Increase the rate of recycling
- Promote purchase and proper use of Energy Star programmable thermostats

Strategies to Achieve the Recommended Approaches:

- Advertise the TRC program among distributors, electrical supply, and plumbing stores as well as construction and demolition companies
- Inform construction and demolition companies about the importance of recycling thermostats containing mercury
- Expand education campaigns on the proper use of Energy Star programmable thermostats
- Phase out the use of mercury-containing models in cases in which energy-efficient non-mercury alternatives may be properly utilized

Sharing Responsibility for Implementation:

As evidenced by the TRC program, several manufacturers already are taking steps aimed at recycling and product substitution. Key stakeholders to involve in continued implementation efforts are the thermostat manufacturers, distributors, construction and demolition companies, and other consumers, as well as federal, state, and local regulatory agencies as appropriate.

Household Thermometers. Between 1.3M and more than 1.4M fever thermometers containing mercury are sold in the Watershed region each year. It is estimated that at least half of these are bought to replace broken or disposed of units. About 380 kg/yr of mercury are released to solid waste. Because of the health risks associated with volatilization of broken mercury units, and the lack of appropriate mercury-cleaning equipment in households, substitution is the preferred option. Non-mercury digital and electronic thermometers can be purchased from $1 to $3 more than those containing mercury.

Several initiatives support the move to complete substitution. For example, many pharmacies have joined a campaign to stop selling mercury thermometers, and at least one county in the Watershed (Westchester) has banned their commercialization. This county and several hospitals throughout the region have organized mercury swaps in which participants can turn in their old mercury thermometers and obtain free digital replacements.

130. The larger estimate includes dentists who use composite material but remove mercury amalgams and recover them from the chair-side traps. These estimates assume three shipments per year per dentist, at a cost of $40 per shipment.

131. http://www.amm.com/REF/merc.htm .

132. Note that if not properly used, programmable thermostats can be less energy efficient than non-programmable thermostats.

133. It has been suggested that some fraction of the mercury from replaced thermostats is stored and not discarded. Eric Erdheim (NEMA), personal communication, November 2001.

134. http://www.nema.org/DocUploads.

P2 and Management Recommendations for Household Thermometers:

- Substitute non-mercury alternatives
- Increase the rate of retiring mercury-containing models

Strategies to Achieve the Recommended Approaches:

- Phase out the sale of all mercury thermometers
- Expand educational campaigns to inform the public about the health risks associated with spills from broken mercury thermometers
- Support and enlarge ongoing efforts aimed at recovering mercury thermometers now in use
- Implement collection and take-back programs

Sharing Responsibility for Implementation:

Many local communities already are participating in collection and take-back programs for household thermometers (see "Action at the Local Level…" Box). To expand these programs and further promote substitution, the following stakeholders will be critical: thermometer manufacturers, pharmacies, state and local governments and regulatory agencies, health officials, and consumers.

3.3. Dredging

There has been ongoing discussion about the effect of maintenance dredging[135] on mercury in the NY/NJ Harbor. First and foremost, note that dredging operations might be beneficial with respect to the removal of one contaminant but harmful in terms of removing another (e.g., dredging a site with high dioxin and mercury concentrations may help remove a potential mercury source, but the disturbance might re-release the dioxins to the water column, causing fish concentrations to increase). Thus, any recommendations on dredging should be site specific, and outcomes for all the contaminants should be considered.

In terms of mercury, dredging could be beneficial, removing contaminated sediments from the Harbor, thereby decreasing the sediment pool available for methylation. Themelis and Gregory calculate that dredging operations between 1930 and 2000 already have removed approximately 6,000 tons of mercury from the Harbor.[136] Conversely, dredging disturbs the sediment and possibly re-releases previously sequestered mercury back into the water column where it can settle to the sediment surface and be available for methylation. Similarly, depending on how deep one dredges, the more recent, cleaner, sediment cap deposited since mercury usage decreased in the 1980s could be removed. This would expose the older, more contaminated sediments deposited during the heavier industrial time period for the region.

The Mercury/Methylmercury Action Group discussed this question in depth and tentatively agreed that older, buried mercury poses a lesser threat than "new" mercury because it tends to be less reactive (it is bound with particles and organic matter). This suggests that maintenance dredging would not have a major negative impact on the mercury cycle in the Harbor unless it occurs near sites where the highest concentrations of mercury may be entering (and presumably settling to the sediment surface nearby). Environmental dredging targeting these sites, however, would need to be carefully assessed as to the benefits and risks posed by the mercury contamination. The Group emphasized the importance of stemming methylation, and thus targeting ongoing sources of mercury, including those documented in this paper as well as potential sources resulting from Superfund and Brownfield sites around the Watershed. Much of this mercury in these latter sites actually may have been dumped on the soils, marshes, and creeks in the past but is entering the Harbor now via leachate, runoff, and groundwater. There are no data on its reactivity, and so it is prudent to assume this mercury is reactive.

Dredge spoils constitute a major problem for this region since the closing of the offshore ocean dumpsite for contaminated materials. Dredged material is being used to cap some of the old brownfields along the Harbor's rivers, after being mixed with cement to form a hard surface that presumably will trap the contaminants at these sites. The question remains as to how long the underlying contaminants stay trapped. Concern was voiced among members of the Action Group about removing contaminated sediments from the Harbor and placing them along shores where contaminants can re-enter the Harbor.

From this admittedly brief discussion of dredging it is clear that valid risk management recommendations cannot be made without consideration of the effects of other contaminants in the Harbor sediments. Thus, as each additional contaminant is studied by the Consortium, under the auspices of the Academy's project, the issue of dredging will be revisited and reassessed.

135. Maintenance dredging refers to dredging undertaken to maintain shipping channels, docks, boating access, etc. Environmental dredging is specifically targeted at removing contaminated sediments.

136. Themelis and Gregory, "Sources and Material Balance for Mercury in the NY/NJ Harbor," p. 24.

4. CONCLUSION

The recommendations for priorities for action, for research priorities, and for pollution prevention and management of mercury were derived through an iterative process over a period of 2 years. First, the Consortium was brought together in January 2000, and suggestions were made as to who else needed to be represented at the table of stakeholders dealing with mercury in the NY/NJ Harbor. Along the way, Academy staff broadened the discussion to include several other interested parties who were not represented directly on the Consortium.

At each step of the process, Consortium members were provided materials generated by commissioned work or internal staff research and asked to review them and to discuss what steps were then needed in terms of further research or developing recommendations. When members of the Consortium agreed it was time to pull together the various strands of information, Academy staff then drafted a document, which was presented to the Consortium at its biannual meeting at the New York Academy of Sciences on December 7, 2001. This document not only incorporated previous research by commissioned consultants and Academy staff, but also included new research by Academy staff, especially in terms of costs and benefits associated with mercury use, recycling, and substitution. Furthermore, the document provided a set of potential P2 and management recommendations.

During that session, the iterative process held true. Although consensus was reached on the recommended priorities for action and research, as well as on several of the P2 and management recommendations and the strategies for achieving them, there were several points of contention. Several members of the Consortium volunteered to serve in small sessions with additional sector representatives to finalize wording on, for example, vehicle and appliance switches, fluorescent lamps, and the dental sector. These sessions were held during February and March 2002 and, once consensus in the smaller groups was reached, the changes were incorporated into the final document presented here.

The final step was to add the who to the discussion of what and how; in other words, the key stakeholders who will need to share responsibility for implementation were identified. The intent of the Consortium was not to point fingers, but to recognize that pollution prevention is a joint effort, and that successful implementation of the recommendations is best achieved when different sectors with varied interests find ways to work collaboratively toward a common goal. Moreover, through the process itself, Consortium members came to see the importance of educational efforts and the inclusion of communities in realizing the goals developed for pollution prevention and management of mercury in the NY/NJ Harbor.

The Consortium members come from various sectors and represent diverse interests. However, they were able to reach a consensus. They recognize that it is now up to them as well as to the rest of the stakeholders mentioned to help implement the recommendations and strategies presented. Pollution prevention measures for mercury have been taken in many places nationally and internationally, with varying degrees of success. Though some of the recommendations included in this document call for difficult decisions, they are all realistic goals, tempered by an understanding of the political, social, and economic complexities of this region.

5. SELECTED BIBLIOGRAPHICAL REFERENCES

Association of Metropolitan Sewage Agencies (AMSA). *Evaluation of Domestic Sources of Mercury*. Washington, DC: AMSA, 2000.

Benoit, Janina M. "Methylmercury Cycling in the NY/NJ Harbor: Implications for Mitigating High Mercury Levels in Harbor Fish." Paper presented at the New York Academy of Sciences, New York City (August 2001).

Boehme, Susan and Marta Panero. "An Industrial Ecology Analysis of Mercury in the New York/New Jersey Harbor. Paper presented at the New York Academy of Sciences, New York City (June 2001).

Brown, Lester R. *Eco-Economy: Building an Economy for the Earth*. New York: WW Norton & Company, 2001.

Center for Sustainable Systems. "Pollution Prevention as Defined under the Pollution Prevention Act of 1990. http://www.umich.edu/~nppcpub/p2defined.html.

ENSR Consulting and Engineering. "The Cost of Compliance of WLSSD with the Great Lakes Water Quality Initiative." Paper presented for WLSSD, Duluth MN 91993.

Environmental Working Group/The Tides Center. *Protecting by Degrees: What Hospitals Can Do to Reduce Mercury Pollution*. (May 1999). http://www.ewg.org.

Fitzgerald, William F. and Joel S. O'Connor. "Mercury Cycling in the Hudson/Raritan River Basin." Paper presented at the New York Academy of Sciences, New York City (February 2001).

Hawkins, Lee, Jr. "Wisconsin Utilities Criticize Plan to Reduce Mercury Emissions." *Milwaukee Journal Sentinel* (4 September 2001).

Hazardous Waste Management Program. Water and Land Resources Division. Department of Natural Resources, *Management of Hazardous Dental Wastes in King County,* 1991-2000. Seattle, WA: LHWMP, October 2000. http://dnr.metrokc.gov

Institute for Sustainable Development. "Policies and Measures to Reduce Greenhouse Gas Emissions: Findings by the International Energy Agency." *Earth Negotiations Bulletin* 1. New York: IISD, October 2001.

Klaassen, Curtis D., ed. Casarett and Doull's *Toxicology: The Basic Science of Poisons,* 5th edition. New York: McGraw-Hill, 1996.

Lake Michigan Forum, et al. *A Guide to Mercury Reduction in Industrial and Commercial Settings*. http://www.delta-institute.org/publications/Steel-Hg-Report-0627011.pdf.

Larrabee, Richard. "Port Development: It Is a Balancing Act." Paper presented for the Metropolitan Waterfront Alliance, New York City (February 7, 2002).

Lifset, Reid J. "Full Accounting." *The Sciences* (May/June 2000): 32–37.

Metropolitan Council Environmental Services (MCES) and Minnesota Dental Association. *Evaluation of Amalgam Removal Equipment and Dental Clinic Loadings to the Sanitary Sewer*. St. Paul, Minnesota: MCES, December 2001.

National Research Council. *Toxicological Effects of Methylmercury*. Washington, DC: National Academy Press, 2000.

New Jersey Department of Environmental Protection. Division of Science, Research & Technology. "A Guide to Health Advisories for Eating Fish & Crabs Caught in New Jersey's Waters." http://www.nj.gov/dep/dsr/njmainfish.htm.

New Jersey Mercury Task Force. *Executive Summary and Recommendations*. http://www.state.nj.us/dep/dsr/mercury_task_force.htm.

New York State Department of Health. "Health Advisories: Chemicals in Sportfish and Game." http://www.health.state.ny.us/nysdoh/environ/fish.htm.

Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District. *Mercury Sector Assessment for the Greater Milwaukee Area* (September 1997). http://www.epa.gov/glnpodocs/milwaukeehg/mercury.pdf.

Pollution Probe. *Mercury in the Health Care Sector: The Cost of Alternative Products*. (Toronto: Pollution Probe, 1996).

RAND. Science & Technology Policy Institute. "Nature's Services: Ecosystems Are More than Wildlife Habitat." http://www.rand.org/scitech/stpi/ourfuture/NaturesServices/section1.html.

__________. "Nature's Services: New York City Watershed." http://www.rand.org/scitech/stpi/ourfuture/NaturesServices/sec1_watershed.html.

Stern, A.H., L.R. Korn, and B.E. Ruppel. "Elimination of Fish Consumption and Methylmercury Intake in New Jersey Population." *Journal of Exposure Analysis and Environmental Epidemiology* 6, 4 (1996): 503–525.

Sznopek, John L. and Thomas G. Goonan. "The Materials Flow of Mercury in the Economies of the United States and the World," *U.S. Geological Survey Circular* 1197. Washington, DC: U.S. Department of the Interior/USGS, 2000.

Themelis, Nickolas J. and Alexander F. Gregory. "Sources and Material Balance of Mercury in the New York–New Jersey Harbor." Paper presented at the New York Academy of Sciences (October 2001).

U.S. Environmental Protection Agency. Office of Air and Radiation. *Mercury Study Report to Congress,* volumes 4, 7, and 8. Washington, DC: U.S. EPA, December 1997.

6. APPENDICES

6.1. Description of Distribution of Mercury from Sector and Products to Air, Wastewater, and Monofills/Landfills

The following pages provide a short explanation of how total mercury releases were calculated and how they are distributed and redistributed among air, water, and solid waste. (See Appendix 6.2 for full calculations of initial releases.) As noted previously, mercury is first released or disposed of into air, water, or solid waste, but through reprocessing is moved to a different pool or pools. The full description of this reprocessing is given for each of the sectors and products below and corresponds to the estimates listed in the Tables, Charts, and Figures throughout this document. We rounded off our estimates for initial releases to the various sectors and products and therefore chose not to round off when describing the reprocessing after initial release. Confidence levels for each of the final distributions of release are considered the same as those levels shown in Table 1 for each of the sectors and products. Tables 6.1 through 6.5 show the redistribution of mercury during intermediate processing.

Automobiles/fuel combustion

The range for mercury released from the combustion of fuel by automobiles is 114 to 202 kg/yr. Both estimates are based on the number of vehicles in the Watershed (7,444,740) multiplied by the average number of miles traveled per vehicle per year (13,000), multiplied by an estimate of how much mercury is released per vehicle mile (2.6×10^{-09} pounds Hg per mile or 4.6 x 10–09 pounds per mile [EPA]).[137] The results are then converted to kilograms per year. The average of these two estimates was rounded to 150 kg/yr released in the watershed. All of the mercury from fuel combustion is released directly into air.

Crematoria

There are 45 crematoria in the Watershed,[138] and each facility performs anywhere from 612 to 778 cremations per year.[139] It is estimated that from 0.6 to 1 g of mercury is released per cremation,[140] resulting in a range of 17 to 35 kg/yr. Using national estimates of cremations[141] and adjusting to regional population[142] gives an estimate of 21 to 35 kg/yr released from crematoria. Averaging these estimates and rounding off gives an estimate of 25 kg/yr released in the Watershed from crematoria. There are no controls for mercury at crematoria. There are no estimates of how much mercury remains with the ashes; therefore it is assumed that all mercury is released into the air.

Dental facilities

Releases of mercury from dental facilities were calculated using both regional and national data. Mercury can be released during the removal of old fillings and during the application of new mercury fillings. These two components are described individually below. Direct measurements of releases to wastewater from dental offices were scaled regionally and used to determine the fraction of the mercury released that enters the wastewater stream.

Removal of amalgams: There are 11,240 dental offices in the watershed.[143] It is estimated that anywhere from 70 to 83% of dentists remove old amalgams. Approximately 400 mg of mercury is removed per amalgam,[144] multiplied by 16 to 17 removals per week,[145] multiplied by 48 working weeks equals 2,417 to 3,045 kg/yr of mercury removed and discarded annually from the Watershed. Alternatively, scaling national estimates of mercury outflows from the dental sector[146] to regional population gives an estimate of 3,191 to 5,877 kg/yr.

Release during new amalgam application: The release of mercury from new amalgams was calculated using mercury usage data from both national estimates and regional data. It is assumed that 15 to 50% of the mercury used is released during placement. This gives an annual release from new amalgams of 409 to 2,939 kg/yr.

137. Michael Aucott, New Jersey Mercury Task Force, personal communication.
138. Compiled from CenStats, http://tier2.census.gov/ cgi-win/zbp/compares
139. http://www.nfda.org/resources/deathstats.html
140. Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District, “Mercury Source Sector Assessment for the Greater Milwaukee Area” (Sept. 1997).
141. www.biomed.lib.umn.edu/hw/cremstats.html
142. 5.8% of national population.
143. Public Information Unit of N.Y. State Education Department (April, 2001); N.J. Board of Dentistry (May 2001).
144. Mary Joy DelConte, A Mercury Pollution Prevention Study for Medical and Dental Centers (1997).
145. Peter Berglund, P.E. Dental Clinics and Other Sources of Mercury to a WWTP (1997).
146. John L. Sznopek and Thomas G. Goonan, The Material Flow of Mercury in the Economies of the United States and the World (2000). U.S. Department of the Interior/USGS.

Summing the regional releases from removal and new application and subtracting out recycling (recycling rates are assumed to be close to 10%) gives an estimate of 2,699 to 5,385 kg/yr available for release from the dental sector. The average of the estimates for releases from dental facilities was rounded to **4,000** kg/yr. Independent measurements and estimates of releases via wastewater were used to determine that approximately 25% of this 4,000 kg/yr makes its way to the wastewater stream. The remainder (3,000 kg/yr) is assumed to be disposed of as solid waste. (See the box below for the description of how solid waste is processed.) Wastewater is treated at the WWTP, and approximately 20% (200 kg/yr) leaves the facility as effluent and directly enters the Harbor. The remaining mercury ends up in the sludge. Sludge can be combusted, buried, or used for land amendment (fertilizer). See box below for description of sludge processing in New York and New Jersey. A full description of the intermediate and final pools for the dental sector is provided below. For all other sectors that send mercury to wastewater and solid waste, the same calculations can be applied. It should be noted that some mercury volatilizes in the dental office, but we were not able to quantify this component for the dental sector.

Dental wastewater: Of the 1,000 kg/yr of mercury that enters the POTW from dental facilities, it is estimated that 5 to 35% (20% average used[147]; 200 kg/yr) is released directly to the watershed as effluent. The remaining 800 kg/yr remains with the sludge. Both New York and New Jersey incinerate about 25% of their sludge. The remaining sludge from New York is used for fertilizer (~50%) and landfill (~25%)[148]; New Jersey uses the clean sludge as land amendment (~65%) within the state, and the remainder (10%) is used as landfill either in New Jersey or out of state. For our calculations, we assumed that all of this 10% is used as landfill within the Watershed because there are no data on the actual distribution. Approximately 70% of sludge comes from New York, and the remaining 30% is from New Jersey. Thus, of the 800 kg/yr of sludge (560 kg from N.Y. and 240 kg from N.J.), 360 kg/yr (25%) is incinerated. Of this 360 kg, about one-third[149] is released into the air (120 kg/yr), and the remainder stays with the ash and is disposed of in landfills or monofills (240 kg/yr).

Dental solid waste: The largest portion of waste from dental offices goes to solid waste (3,000 kg/yr). About one-third (1,000 kg) of the solid waste is incinerated in waste-to-energy facilities.[150] These facilities have controls in place. Thus, only 3.5%[151] of the mercury is released to the atmosphere (35 kg/yr), and the remainder (965 kg/yr) is in the ash that goes to landfills or monofills. The remaining two-thirds of solid waste (2,000 kg/yr) goes to landfills.

Thus, the total releases from dental facilities to air (101 kg/yr: 35 kg from solid waste combustion plus 66 kg from sludge incineration); to wastewater effluent (200 kg/yr); to fertilizer (436 kg/yr); and to landfills/ monofills (3,263

DISTRIBUTIONS FOR ALL PRODUCTS AND SECTORS SENDING MERCURY TO WASTEWATER

Total wastewater → 70 to 95% to sludge, 5 to 30% is effluent (using 20% as average)

Sludge: 70% from New York; 30% from New Jersey

N.J. sludge: 25% combusted (33% to air; 67% to ash (landfill/monofills))
65% to fertilizer
10% to landfills

N.Y. sludge: 25% combusted (33% to air, 67% to ash (landfill/monofills))
50% to fertilizer
10% to landfills

147. 1998 Headworks Analysis, NYC-DEP; Nickolas J. Themelis and Alexander F. Gregory, 2001; Phil Heckler and Simon Litten, personal communication.
148. NYS DEC. Biosolids Management in New York State (1998).
149. N. Themelis, personal communication.
150. NYS DEC, Division of Solid and Hazardous Materials. Capacity Data for Landfills and Waste to Energy Facilities (June 2001).
151. Ajay Shroff, NYS DEC, personal communication.

DISTRIBUTIONS FOR MERCURY-BEARING PRODUCTS AND SECTORS SENT TO MWC AND WTE FACILITIES

Approximately one-third of solid waste goes to MWC and WTE facilities. These facilities have controls to trap mercury, and therefore only 3.5% of the mercury entering is released. The remainder goes to ash or is captured by a control system and sent to monofills. The proportion (two-thirds) of solid waste that does not go to the MWC and WTEs is sent directly to landfills.

DISTRIBUTIONS FOR MERCURY-BEARING PRODUCTS SENT TO EAFs

EAF facilities do not have controls in place for trapping mercury during combustion. Automobiles and appliances are sent to EAFs in the Watershed. Approximately one-third of the mercury is released to the atmosphere, and the remainder is associated with the ash.

kg/yr: 965 kg/yr from incinerated solid waste ash, 2,000 kg/yr direct to landfills from solid waste, 134 kg/yr from sludge incineration ash and 164 kg/yr from sludge direct to landfills) sums to the total releases of 4,000 kg/yr from dental facilities.

Hospitals

Releases of mercury from hospitals were calculated by summing the individual releases from thermometers, sphygmomanometers, dental clinics, and laboratories in hospitals.

Thermometers: Release of mercury from thermometers in hospitals is calculated on a one thermometer per bed[152] basis and an assumed 10% yearly breakage rate.[153] There are 85,883 hospital beds/thermometers in the Watershed with a mercury content of 0.7 g per unit,[154] resulting in **6** kg/yr released from thermometers in hospitals.

Sphygmomanometers: There is approximately one mercury sphygmomanometer per hospital bed in the Watershed, and of these, 90% are wall mounted (4% per year breakage rate) and 10% are mobile units (10% per year breakage rate). Each unit contains approximately 90 g of mercury,[155] resulting in a release of **356** kg/yr. About 10% of this release is assumed to volatilize directly to the air.

Dental Facilities in Hospitals: Releases from dental facilities are calculated in the same way as described in the dental section above. Dental clinics in hospitals use 59 kg/yr of mercury in new restorations.[156] A range of 15 to 50% of this mercury is released during placement, giving a release of 9 to 30 kg/yr. In addition, 36 kg/yr[157] are released during the removal of old amalgams. Summing these two sources gives an estimate of **44** to **66** kg of mercury released yearly from hospital dental clinics.

Laboratories: Laboratories within hospitals add an additional **1,002** kg/yr, based on national estimates adjusted for regional population and accounting for the number of laboratories in hospitals. National estimates calculate that 28,000 kg[158] of mercury outflow from U.S. laboratories annually. Adjusting this value to the regional population (5.8% of the national estimate) gives an estimate of 1,624 kg for the region's laboratories. There are 705 laboratories in the Watershed, of which 435 are in Watershed hospitals.

Summing the four sources of mercury releases from hospitals (6 kg/yr from thermometers, 356 kg/yr from sphygmomanometers, 44 to 58 kg/yr from dental clinics, and 1,002 from laboratories) gives an estimate of 1,408 to 1,430 kg/yr of mercury. Approximately 40 kg are recycled. Thus 1,400 kg/yr (rounded) are available for release from the hospital sector. Of this 1,400 kg/yr, **60** kg is released into the air via volatilization, **700** kg/yr to wastewater, and **640** kg/yr to solid waste. As described in the dental sector, further treatment and processing of solid waste and wastewater result in a final distribution for the three pools as fol-

152. www.hospitalselect.com
153. Barr Engineering Company. Substance Flow Analysis of Mercury in Products. Prepared for the Minnesota Pollution Control Agency (August 2001).
154. Ibid.
155. MERC-Pollution Probe (November 1996).
156. See Appendix 6.2 Hospital Uses for full explanation.
157. Ibid.
158. John L. Sznopek and Thomas G. Goonan (2000). "The Materials Flow of Mercury in the Economies of the U.S. and the World," U.S. Geological Survey Circular 1197.

lows: air, **114** kg/yr; effluent, **140** kg/yr; fertilizer, **305** kg/yr; and landfills, **841** kg/yr. It should be noted that recent estimates of releases from hospitals to wastewater based on measurements (taken at the manholes) of the wastewater leaving hospitals in Boston and Milwaukee calculated much lower releases, even when scaled to the Watershed hospitals. We have not included these estimates because the Milwaukee hospitals are mercury-free and the Massachusetts Water Authority has been working with hospitals for a number of years to reduce mercury usage and releases. There are no such programs being implemented in the Watershed at this time.

Households

The major releases from households include those from residential furnaces (**150** kg/yr all released into air during combustion[159]), thermometers (**500** kg/yr), household products, and domestic wastewater (**350** kg/yr) (Association of Metropolitan Sewage Agencies (AMSA), *Evaluation of Domestic Sources of Mercury* [2000]).

Thermometers: Releases of mercury from household thermometers are estimated on the basis of the number of thermometers sold per household in the Watershed (1,384,622) and the assumption that 50% of the thermometers sold are replacing broken units.[160] Each broken thermometer contains, on average, 0.7 grams of mercury, resulting in a release of 485 kg/yr (rounded to **500** kg/yr). Approximately 10% (50 kg/yr) is volatilized directly into the air, and 20% (100 kg/yr) goes to wastewater. The remaining portion goes to solid waste (350 kg/yr).[161] After secondary treatment of solid waste and sludge from thermometers, **61** kg are released into the air, **44** kg ends up in fertilizer, **20** kg is released as effluent, and **375** kg is disposed of in landfills and monofills.

Household products and wastewater releases: The average discharge of mercury per household is 138 ng/liter.[162] Multiplying this by an estimate of domestic wastewater treated yearly by NYC POTWs (1.46 x 1012 liters per year)[163] and scaling from NYC population to the regional population gives an estimate of 360 kg (rounded to 350 kg/yr) discharged to wastewater from households. As noted above, 100 kg/yr is accounted for by thermometer disposal. The sources of the remaining 250 kg of mercury are products and human waste (trace quantities of mercury in foods, beverages, products, and from dental amalgams.[164] This **250** kg/yr of mercury is all in the wastewater; and, after wastewater treatment, 20% (**50** kg) is released as effluent, and the remaining 80% (200 kg) ends up in the sludge. After sludge treatment, **17** kg/yr are released into the air from incineration, **109** kg/yr end up in fertilizer, and **75** kg/yr goes to landfills and monofills.

Industrial Commercial Furnaces/Utilities/Residential Furnaces

Themelis and Gregory[165] estimate that 330 kg/yr (rounded to **350** kg/yr) are released from industrial and commercial furnaces, 383 kg/yr (rounded to **400** kg/yr) are released from utility furnaces, and 160 kg/yr (rounded to **150** kg/yr) are released from residential furnaces in the Watershed. All of this mercury is released to the atmosphere during combustion.

Laboratories (non-hospital)

See description above for laboratories in hospitals for full description and references. Of the 705 laboratories in the watershed, 270 are non-hospital laboratories. (The remaining 435 laboratories are accounted for in the Hospital section). Each facility releases approximately 2.3 kg/yr of mercury, resulting in a release of 622 kg/yr (rounded to **600** kg/yr). Of the 600 kg/yr released, 15 kg/yr (2.5%) is volatilized, 400 kg/yr goes to wastewater (67%), and the remaining 31%, or 185 kg/yr per year, goes to solid waste.[166] After secondary treatment and processing of solid waste and sludge, **44** kg/yr are released into the air through incineration and volatilization, **80** kg/yr are released as effluent, **174** kg/yr end up in fertilizer, and **302** kg/yr goes to landfills and monofills.

Batteries

Mercury is still used in some button cell batteries, but production of regular mercury batteries in the U.S. has been

159. Nickolas J. Themelis and Alexander F. Gregory. “Sources and Material Balance of Mercury in the New York–New Jersey Harbor.” Paper presented at the New York Academy of Sciences (October 2001). Table 5, page 13.
160. Extrapolated from Substance Flow Analysis of Mercury in Products (August 2001). Prepared for the Minnesota Pollution Control Agency dby Barr Engineering Company using regional census data to estimate the number of households in the region (5,769,258).
161. Ibid.
162. New York City Department of Environmental Protection Headworks Analysis (1998).
163. Ibid. and P. Heckler and R. Lochan, personal communication.
164. AMSA, Evaluation of Domestic Sources of Mercury, (2000).
165. Nickolas J. Themelis and Alexander F. Gregory. “Sources and Material Balance of Mercury in the New York-New Jersey Harbor.” Paper presented at the New York Academy of Sciences (October 2001).
166. John L. Sznopek and Thomas G. Goonan. “The Materials Flow of Mercury in the Economies of the U.S. and the World,” U.S. Geological Survey Circular 1197.

banned since the 1980s, and the importation of mercury-containing batteries was halted in the mid-1990s. Approximately 2000 kg of mercury in button cell batteries was sold in the year 2000.[167] Scaling for the regional population gives an estimate of nearly 120 kg/yr. A conservative estimate for button cell battery recycling for the region is 10%.[168] Assuming that batteries being sold are replacing those being thrown away produces an estimate of approximately **100** kg/yr for release of mercury after subtracting out the recycled mercury. It is assumed that all of the batteries are sent to the trash; and, after processing of solid waste (see description of solid waste steps in box above), about **1** kg/yr is released into the air through incineration, and **99** kg/yr goes to landfills and monofills.

Fluorescent Lamps

The mercury released from fluorescent lamps in the Watershed was calculated in two ways: (1) Using national data on estimates of mercury releases from discarded fluorescent tubes (20,000 kg) scaled to regional population (5.8%) and assuming a recycling rate of 20% gives a mercury release of 1,040 kg/yr. (2) Using national estimates of the three major lamp size groups sold in the Watershed multiplied by their average mercury content (assuming that every lamp sold is replacing a discarded lamp that was originally purchased in 1996) gives an estimate of 741 kg/yr. (It is assumed that lamps discarded in 2001 were produced 5 years earlier. Mercury content has been steadily decreasing in fluorescent lamps).[169] Recycling rates of lamps vary regionally, and this region is believed to have a low rate of recycling; because no real estimate could be obtained, the national estimate of 20% was used.[170] Thus the average amount of mercury released from fluorescent lamps is 712 kg/yr, rounded to **700** kg/yr. Of this 700 kg, approximately 25%,[171] or 175 kg/yr, volatilizes. The remaining mercury (**525** kg/yr) goes to solid waste. After secondary treatment and processing of solid waste, **181** kg/yr is released into the air from volatilization and incineration, and the remainder (**593** kg) goes to landfills and monofills.

Switches

Switches in cars, appliances, and lighting fixtures can contain mercury. Cars and appliances generally are sent to shredders and scrap yards and eventually are sent to EAFs for smelting. Lighting fixtures are disposed of in the trash as solid waste.

Lighting: Discarded switches from the lighting industry are typically sent to regular trash or demolition debris. National estimates for disposal of mercury in switches (1,930 kg/yr[172]) were scaled to the regional population (5.8%), resulting in a regional estimate of 112 kg (rounded to **100** kg/yr of mercury available for release in the Watershed). Assuming all of this mercury goes to solid waste, the final distributions after processing of solid waste are: **1** kg/yr released into the air from incineration and **99** kg/yr to landfills and monofills.

Appliances: The number of mercury switches in appliances has decreased drastically in the last 10 years. Only one gas pilot range is still being made with a mercury switch. Appliances being disposed of now, however, may still contain mercury switches, and so there is still a small source of mercury from the disposal of appliances. This number will drop with time as the older appliances are discarded. There are close to 6 million households in the Watershed, and it is estimated that 0.35 appliances are discarded per household each year.[173] The average mercury content of appliances is 0.001 kg,[174] resulting in **25** kg/yr released from this sector. Because appliances are generally sent to smelting facilities that do not have mercury collection devices, approximately **7** kg/yr is released to air, and the remainder (**18** kg) is buried in landfills and monofills.

Automobiles: Estimates for mercury releases from automobile switches are based on a number of different calculations. Using an estimate of the number of cars in the Watershed (over 7 million), a disposal rate of 10%,[175] and an average amount of mercury in switches per car (0.001 kg[176]) and accounting for a 6% recycling rate gives an estimate of 700 kg/yr. Alternatively, using the national estimates of numbers of vehicles retired each year (12 million[177]), adjusted for regional population (5.8% of the

167. Barr Engineering Company. Substance Flow Analysis of Mercury in Products. Prepared for the Minnesota Pollution Control Agency (August, 2001).
168. Leo Cohen, Mercury Refining Corporation, Albany NY, personal communication.
169. Fluorescent Lamps and the Environment; http://www.nema.org
170. B. Jantzen, personal communication.
171. Estimates for volatilization range from 20 to 80%. We used the 25% cited by the N.J. Mercury Task Force and Barr Engineering Company, Substance Flow Analysis of Mercury in Products, prepared for the Minnesota Pollution Control Agency (August 2001).
172. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997). "Mercury Source Sector Assessment for the Greater Milwaukee Area."
173. Ibid.
174. Ibid.
175. T. Corbett, NYS DEC Mercury Reduction Plan, personal communication.
176. Ibid.
177. Charles Griffith, Jeff Gearhart and Hans Posset (January 2001). Toxics in Vehicles: Mercury—Implications for Recycling and Disposal.

national) and assuming a switch to vehicle ratio of 1.6[178] and a mercury content of 0.001 kg, gives an estimate of 837 kg/yr for the Watershed (assuming the 6% recycling rate). A third calculation is based on estimates of how much mercury is in cars on the road in the Watershed (9,976 to 11,600 kg) and a disposal rate of 10% yearly. After accounting for a 6% recycling rate, this gives an estimate of 938 to 1,090 kg/yr released. An average of these calculations gives an estimate of 891 kg rounded up to **900** kg/yr. All of the cars are sent to EAFs to recover the metals. Approximately one-third, or **300** kg/yr, is released to the air during the smelting process, and the remainder (**600** kg/yr) is sent to landfills/monofills as ash/waste.

Thermostats

The releases of mercury from thermostats was calculated using estimates of the number of units disposed of nationally (2,619,000),[179] adjusted for regional population and the average mercury concentration per thermostat (4 grams[180]), resulting in 607 kg/yr of mercury available for release. This number was corrected for the amount of mercury recycled in thermostats in the region (10 kg)[181] and rounded off to **600** kg/yr. This mercury is sent to solid waste (trash and demolition debris). After processing of solid waste (see description of solid waste steps in box above), approximately **7** kg/yr is released to air from incineration and **593** kg/yr goes to landfills and monofills.

Summary of releases

The following tables summarize the previous descriptions for the distribution of the mercury after initial release through intermediate processing (where applicable) through final release to air, water, fertilizer, and landfills and monofills. Note that mercury associated with ash after incineration is sent to landfills and monofills.

178. Ibid.

179. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997). “Mercury Source Sector Assessment for the Greater Milwaukee Area.”

180. http://www.nema.org

181. Ibid. Thermostat Recycling Corporation statistics are on this web page.

TABLE 11. *Initial* Releases of Mercury to Air, Wastewater, and Solid Waste

Initial Releases	Total kg/yr	To Air via Combustion	To Air via Volatilization	To Waste-water	To Solid Waste
Automobiles/fuel combustion	150	150			
Crematoria	25	25			
Dental facilities	4,000			1,000	3,000
Hospitals	1,400		60	700	640
Households: Furnaces	150	150			
Products/waste	250			250	
Thermometers	500		50	100	350
Industrial/commercial furnaces	350	350			
Laboratories	600		15	400	185
Utilities: Furnaces	400	400			
Batteries	100				100
Fluorescent lamps	700		175		525
Switches (appliances)	25				25
Switches (vehicles)	900				900
Switches (lighting)	100				100
Thermostats	600				600
TOTAL	**10,250**	**1,075**	**300**	**2,450**	**6,425**

TABLE 12. Intermediate Releases from Wastewater

Intermediate Releases	Dental Facilities	Hospitals	Household Products	Thermo-meters	Labora-tories	Total
Initial release to wastewater	1,000	700	250	100	400	
20% to effluent	200	140	50	20	80	**490**
80% to **Sludge**	800	560	200	80	320	
70% of sludge is from N.Y.	560	392	140	56	224	
30% of sludge is from N.J.	240	168	60	24	96	
Sludge	800	560	200	80	320	
Incineration (25% both states)	200	140	50	20	80	
To air from incineration	66	46	17	7	26	**162**
Remainder to landfill ash	134	94	34	13	54	**329**
Fertilizer (50% NY; 65% NJ)	436	305	109	44	174	**1,068**
To landfill (25% NY; 10% NJ)	164	115	41	16	66	**402**

TABLE 13. Intermediate Releases from Solid Waste (SW) to MWC (kg/yr)

Intermediate releases	Initial release To SW	One-third of SW to Incineration (MWC)	To air from Incineration (3.5%)	To ash from Incineration (96.5%)	Two-thirds of SW directly to landfill
Dental facilities	3,000	1,000	35	965	2,000
Hospitals	640	213	7	206	427
Household thermometers	350	117	4	113	233
Laboratories	185	62	2	60	123
Batteries	100	33	1	32	67
Fluorescent lamps	525	175	6	169	350
Switches (lighting)	100	33	1	32	67
Thermostats	600	200	7	193	400
TOTAL	**5,400**	**1,833**	**64**	**1,769**	**3,667**

TABLE 14. Intermediate Releases from Solid Waste to EAF (kg/yr)

Intermediate releases	Initial release	All to Incineration	To air from Incineration (1/3)	To ash from Incineration (2/3)
Switches (appliances)	25	25	8	17
Switches (vehicles)	900	900	300	600
TOTAL	**925**	**925**	**308**	**617**

TABLE 15 Final Releases (kg/yr) (Summary of Tables 11 to 14)

Final Releases	Air	Effluent	Fertilizer	Landfill/ monofill	Total
From wastewater	162	490	1,068	731	
From solid waste to MWC	64			5,436	
From solid waste to EAF	308			617	
Combustion	1,075				
Volatilization	300				
TOTAL	**1,909**	**490**	**1,068**	**6,783**	**10,250**

6.2 Use and Release Spreadsheets

Automobiles—Internal Fuel Combustion — *Mercury Usage*

SUMMARY

No intentional usage of mercury in automobiles
Only incidental releases

Automobiles—Internal Fuel Combustion — *Mercury Available for Release*

SUMMARY

Range of releases

	kg/yr	Confidence level
Calculation # 1	114	M/L
	202	M/L
Average	158	+/- 44

Automobile emissions (kg/yr)	
(Based on Estimated Range)	(Based on Confidence level)
150 +/- 50	**150 +/- 60%**

CALCULATION # 1

	Range		
	4,590,000	4,590,000	registered cars in NY watershed region[1]
+	2,854,740	2854,740	registered cars in NJ watershed region[2]
	7,444,740	7,444,740	total number of registered cars in watershed
x	13,000	13,000	miles travelled per autombile per year[3]
	96,781,620,000	96,781,620,000	miles travelled by all automobiles registered in the watershed per year
x	2.6E-09	4.6E-09	mercury released per travelled mile (in lb)[4]
	252	445	mercury released per year by all automobiles registered in watershed (lb)
	114	**202**	mercury released per year by all automobiles registered in watershed region (kg)

NOTES

1. Census 2000; http://www.census.gov/population/www/estimates/statepop. New York State population in 2000 was 18,976,457. The NY State population in the watershed area is 10.4 million, or almost 54% of the state population. There are approximately 8.5 million registered cars in New York state (http://www.albany.net/~gra/newsltrs.1998/nov98.htm).
2. Census 2000; http://www.census.gov/population/www/estimates/statepop.html. The population in the NJ State in 2000 was 8,414,350 and for the watershed 4.2 million. This represents about 49% of the state population. There are 5,826,000 registered cars in the state of New Jersey (http://www.bergen.com/special/autos/19400611.htm), of which 49% are assigned to the watershed.
3. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997); *Mercury Source Sector Assessment for the Greater Milwaukee Area.*
4. The higher estimate is by EPA (1997); the lower estimate is based on more recent measurements of mercury in gasoline (Michael Aucott, NJ Mercury Task Force, personal communication, October 2001).

Batteries — *Mercury Usage*

SUMMARY

	kg*	Confidence Level
Calculation 1:	116	M
Calculation 2:	119	M/L
	118	**+/-1.5**

Batteries—Usage (kg/yr)	
(Based on estimated range)	(Based on Confidence level)
125 +/-5	**125 +/- 60%**

CALCULATION # 1

	2,000	kg of mercury in batteries sold in the U.S. in the year 2000[1]
x	5.8	% of the US population in the watershed region[2]
	116	kg of mercury in batteries sold in the watershed region in the year 2000

CALCULATION # 2

	29,700	flasks of mercury used by the U.S. battery industry in 1984[3]
x	76	lbs. per flask
	2,257,200	lbs. consumed by the battery industry in 1984
x	0.05	% consumption of mercury by the U.S. battery after regulation[3]
	1,129	lbs. consumed by the battery industry
x	2.2	kg per lb.
	513	kg of mercury consumed by the U.S. battery industry after regulation
x	4	imported batteries in the year 2000 represent 75% of the U.S. battery market[4]
	2052	kg of mercury in all batteries (domestic and imported) sold in the U.S. in the year 2000
x	5.8	% of the US population in the watershed region[2]
	119	kg of mercury consumed in the watershed region

NOTES

* Based on year 2000 data; usage of button cell batteries containing mercury is decreasing as substitutes are now available.

1. Barr Engineering Company (August, 2001); *Substance Flow Analysis of Mercury in Products;* prepared for Minnesota Pollution Control Agency. Barr Engineering Co., 4700 77th street, Minneapolis MN 55435. This estimate includes imported batteries (75% of the U.S. batteries are imported).
2. Census 2000; the US population in 2000 was 285.3 million. The population in the NY State are of the watershed is 10.4 million and in NJ is 4.2 million, for a total of 5.2% of the US population. When adjusted by the level of economic activity in the region, the estimate rises to 5.8% of the national population. http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc/bea/regional/spi.
3. The battery industry reports that the United States battery industry's 1994 consumption of mercury was 99.41% less than its 1984 consumption rate (29,700 flasks in 1984, one flask = 76 pounds, to 174 flasks in 1994.) During this same time period, annual sales of alkaline batteries in the United States increased 150%. http://www.epa.gov/glnpo/bns/mercury/stephgapp.html
4. Barr Engineering Company (August, 2001)

Batteries — *Mercury Available for Release*

SUMMARY

	kg*	Confidence level
Calculation # 1	**106**	L

Batteries—Estimated releases (kg/year)
(Based on Confidence level)
100 +/- 70%

CALCULATION # 1

118	kg of mercury in batteries sold in the watershed region in the year 2000[1]
10	% recycling rate[2]
12	kg recycled
106	kg of mercury disposed of in the Watershed in button cell batteries[3]

NOTES

* Usage of button cell batteries containing mercury is decreasing as substitutes are now available. This will result in reduced releases in the future.

1. For explanation of how this estimate was calculated, see Batteries Usage Section; for this calculation we assume that batteries being sold are replacing batteries that are being disposed. Mercury button cell batteries are in the process of being phased out, however the phase out rate is slower than predicted by the industries involved.
2. Maximum rate; pers. comm. Leo Cohen, Mercury Refining Corporation, Albany NY

Crematoria — Mercury Usage

SUMMARY

No intentional usage of mercury in crematoria
Only incidental releases

Crematoria — *Mercury Available for Release*

SUMMARY

Range of releases

	kg/yr	Confidence level
Calculation # 1	17	M
	35	M
Calculation # 2	19	M
	32	M
Average	**25**	**+/- 9**

Crematoria (kg/yr)	
(Based on Estimated Range)	(Based on Confidence level)
25 +/- 10	**25 +/- 50%**

CALCULATION # 1

	Range		
	45	45	crematories in the watershed area (servicing 430 cemeteries)[1]
x	612	778	average cremations per crematoria[2]
	27,540	35,010	average number of cremations in region
x	0.0006	0.001	kg released per cremation[3]
	17	**35**	kg of mercury released by crematories in the watershed

CALCULATION # 2

	Range		
	606,307	606,307	cremations in the US in year 2000[2]
x	5.2 %	5.2	% of the US population in the watershed[4]
	31,528	31,528	cremations in the watershed in year 2000[2]
x	0.0006	0.001	kg released per cremation[3]
	19	**32**	kg of mercury released by crematories in the watershed

NOTES

1. Information was compiled from CenStats (1997SIC Comparison) Zip Code Business Patterns at http://tier2.census.gov/cgi-win/zbp/compares
2. http://www.nfda.org/resources/cremationstats.html Statistics for New Jersey are as follows: 21,623 cremations in 1999. Adjusting this figure to the watershed area (49% of the state), results in 10,595 cremations. In New York State there were 16,947 recorded cremations in 1999. Adjusting this statistic to the watershed area (54% of the state), results in 16,947 cremations. The total number of cremations in the watershed is 27,542 or 612 cremations for each of the 45 crematoria in this region. The higher estimate of 778 cremations per crematoria is given at www.biomed.lib.umn.edu/hw/cremstats.html
3. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997); *Mercury Source Sector Assessment for the Greater Milwaukee Area* reports actual measurements from a Swedish study as 0.6 grams of Hg per cremation and gives a higher estimate of 1 gram of Hg per cremation in U.S, assuming that Americans use more mercury amalgams than the Swedish population.
4. The U.S. population in 2000 was 285.3 million. The population in the NY State area of the watershed is 10.4 million and in NJ is 4.2 million or a total of 5.2% of the US population. http://www.census.gov/population/www/estimates/statepop.html. No adjustment to the level of economic activity is granted here.

Dental Sector* — *Mercury Usage*

SUMMARY

	kg/yr	Confidence Level
Calculation 1:	2,644	M
	3,582	M
Calculation 2:	3,191	M/L
	5,877	M/L
Calculation 3:	2,725	M/L
Average	**3,604**	**+/- 1326**

Dental Sector Usage (kg/yr)	
(does not include mercury amalgams removed)	
(Based on Estimated Range)	(Based on Confidence level)
3,600 +/- 1,300	**3,600 +/- 60%**

CALCULATION # 1

	Range		
New mercury amalgams:	11,240	11,240	dentists in watershed[1]
x	70%	83	% dentists likely to use mercury amalgams[2]
	7,868	9,329	dentists in watershed using mercury
x	14	16	mercury amalgams completed per dentist per week, on average[3]
	110,152	149,267	mercury amalgams completed by dentists in watershed/week
x	48	48	weeks per year[4]
	5,287,296	7,164,826	mercury amalgams completed by dentists in watershed/year
x	0.0005	0.0005	kg of mercury used per amalgam (median spill size)[5]
Subtotal A	**2,644**	**3,582**	kg of hg used at dental offices
*Mercury amalgams removed:***	11,240	11,240	dentists in watershed (all dentists remove mercury amalgams)[1]
x	70%	83	% dentists likely to use mercury amalgams[2]
	7,868	9,329	dentists in watershed using mercury
x	16	17	amalgams removed per dentist per week, on average[3]
	125,888	158,596	mercury amalgams removed by dentists in watershed/week
x	48	48	weeks per year[4]
	6,042,624	7,612,627	mercury amalgams removed by dentists in watershed/year
x	0.0004	0.0004	kg of mercury removed per old amalgam[6]
Subtotal B	**2,417**	**3,045**	kg of mercury removed by all dentists in watershed
Total	**5,061**	**6,627**	kg of mercury mobilized in dental offices per year

CALCULATION # 2

Mercury usage by dental sector:

	Range		
	0.00169	0.002625	kg managed/dentist/day[7]
x	240	240	working days[4]
	0.4056	0.6300	kg of mercury managed/dentist/year
x	7,868	9,329	dentists in watershed working with mercury amalgams[1]
	3,191	**5,877**	kg of mercury managed/dentists/year in watershed[2]

CALCULATION # 3

Mercury inflows:		48,000	kg of mercury used nationwide by the dental sector per year[8]
	x	5.8	% of the US population in the watershed[9]
		2,784	kg of mercury used in the watershed
	-	59	mercury used by dental clinics in hospitals (see page on hospital use of mercury amalgam)
	Total:	**2,725**	used by dental offices in region

NOTES

* Does not include dental clinics at hospitals. These are accounted for in the hospital sector.

**To provide a picture of how much Hg is mobilized in dental offices per year (from amalgams used and removed).

1. There are 17,026 licensed and registered dentists in New York State, with 6,073 dentists in the NY watershed area. (Rita St. John, Professional, Licensing Services, Public Information Unit of NY State Education Department, personal communication, April 2001). There are approximately 10,000 dentists in NJ State (NJ Board of Dentistry, Licensing Board, May 2001); and about 5,167 dentists within the NJ watershed area (Grace Garcia, Division of Consumer Affairs, NJ; personal communication, April 23, 2001).
2. The estimate of dentists using mercury ranges from 70% to 83% of the total. Not all dentists use mercury, either because they are specialists (e.g. orthodontists) or they have already substituted for non-mercury amalgam. The Water Environmental Federation (1999) *Controlling Dental Facility Discharges in Wastewater: How to Develop and Administer a Source Control Program.* Also, NYC DEP (November 1999) *1998 Headworks Analysis Report.*
3. A survey of dentists by a POTW in Minnesota, indicates that the average rate of placing filings is 17.9 per week per general dentist, and 17.6 removed filings on average per dentist per week. Another estimate indicates that the average rate of amalgam placement for all dentists is 14 restorations per week since specialists (e.g., orthodontists) are not involved in amalgam restorations. Information from: Metropolitan Council Environmental Services (1997) *Dental Clinic and Other Sources of Mercury to a WWTP* (Peter Berglund, P.E., MCES, St. Paul, MN). Another report in Seattle indicates similar rates (17 removed and 16 placed per dentist per week). The Water Environment Federation (1999) *Controlling Dental Facility Discharges in Wastewater: How to Develop and Administer a Source Control Program,* (WEF, Alexandria, VA).
4. Most reports, including those cited above, assume that dental offices operate for an average of 48 weeks, or 240 days, per year.
5. The average mercury restoration contains 500 mg of mercury. There are various spill sizes, depending on the size of the restoration: single (327mg of Hg), double (491mg), and triple (654 mg). Some restorations require a larger amalgam spill (with 982 mg) but this number has not been included in the calculation because there is very little data on this spill size usage. Information from The Water Environment Federation (1999), *Controlling Dental Facility Discharges in Wastewater: How to Develop and Administer a Source Control Program* (WEF, Alexandria, VA). Also http://www.sullivanschein.com (amalgam distributor) for mercury content of different spill sizes.
6. It is estimated that approximately 80% of the mercury used in amalgam restorations is released during replacement. Mary Joy Del Conte (1997) *A Mercury Pollution Prevention Study for Medical and Dental Centers,* Findings Report; prepared for the Monroe County Mercury Pollution Prevention Task Force. Rochester, NY.
7. The quantities of amalgam used are based on an annual estimate of 0.9 to 1.4 kg of amalgam per dentist in the U.S. Since amalgam contains only 45% mercury, and assuming dentists work 240 days per year, the daily estimate is 0.00169 to 0.002625 kg of mercury per dentist/day. Water Environmental Federation (1999) *Controlling Dental Facility Discharges in Wastewater - How to Develop and Administer a Source Control Program.*
8. Total consumption of mercury by the dental sector in the U.S. fluctuates annually; the average from 1986 to 1997 is 48 tons/yr. John L. Sznopek and Thomas G. Goonan, *The Material Flow of Mercury in the Economies of the United States and the World,* US Geological Circular 1197 (Washington, DC: US Department of the Interior and USGS, 2000. Also, Naval Dental Research Institute (January 2000); *Scientific Review of Issues Impacting Dentistry, 2* (1).
9. Census 2000; US population in 2000 was 285.3million. The population in the NY State area of the watershed is 10.4 million and in NJ is 4.2 million or a total of 5.2% of the US population. When adjusted by the level of economic activity in the region, the estimate rises to 5.8% of the national population. http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc./bea/regional/spi.

SUMMARY

	kg/yr	Confidence level
Calculation # 1	2,532	M/L
	5,385	M/L
Average	**3,959**	**+/-1,136**

(For wastewater discharges only)

	kg/yr	Confidence level
Calculation # 2	472	M/L
	1,731	M/L
Calculation # 3	534	M/L
	1,013	M/L
Average	**937**	M/L

24 % of total releases from dental offices are discharged to wastewater

Dental Sector (kg/yr)

(Based on Estimated Range)	(Based on Confidence level)
4,000 +/- 1,100	**4,000 +/- 60%**

Wastewater discharges only
25% of total releases: **1,000 +/- 60%**

CALCULATION # 1

Total releases from dental offices

	Range		
	2,644	5,877	kg/yr of mercury used in application of new mercury amalgams[1]
x	15 %	50	% of mercury used during application becomes waste[2]
	397	2,939	kg/yr available for release from application of dental amalgam
+	2,417	3,045	kg/yr of mercury released during removal of old amalgam[3]
Sub-total	2,814	5,984	kg/yr available for release
–	281	598	kg/yr recycled (assuming a 10% recycling rate)
Total	2,532	5,385	kg/yr released

CALCULATION # 2

Water Discharges Only

	Range		
	11,240	11,240	dentists in the watershed region[4]
x	70 %	83	% dentists in watershed use mercury[5]
	7,868	9,329	dentists in watershed using mercury
x	0.000250	0.000773	kg of mercury discharged per dentist per day[6]
	1.97	7.21	kg of mercury discharged by all dentists in watershed region per day
x	240	240	working days in a year[7]
	472	1,731	kg of mercury released from dental offices in Watershed per year

CALCULATION # 3

Water Discharges Only

Median mercury discharge from dental chairs

	Range		
	11,240	11,240	dentists in the watershed region[4]
x	70 %	83%	dentists in watershed use mercury[5]
	7,868	9,329	dentists in watershed using mercury
x	1	1.6	dental chairs per dentist[5]
	7,868	14,927	dental chairs in watershed
x	88 %	88	% of dentists use 210 micron filter + chairside filter[5]
	6,924	13,136	dental chairs using 210 micron filter + chairside filter
x	0.00025	0.00025	kg of mercury (median release from each dental chair with 210 micron filter plus chairside filter)[5]
	2	3	kg of mercury released/day from dental chairs using both filters in watershed
x	240	240	working days[7]
Sub-total A	415	788	kg of mercury released by dental offices using both filters per year
	11,240	11,240	dentists in the watershed region[4]
	70 %	83	% dentists in watershed use mercury[5]
	7,868	9,329	dentists in watershed using mercury
x	1	1.6	dental chairs per dentist[5]
	7,868	14,927	dental chairs in watershed
x	0.12	0.12	use only a chairside filter[5]
	944	1,791	dental chairs using only a chairside filter
x	0.000522	0.000522	kg of mercury released/day/dental chair using only a chairside filter[5]
	0.49285	0.93501	kg of mercury released/day/dental chair using only chair-side filters
x	240	240	working days[7]
Sub-total B	118	224	kg of mercury released by dental offices using only chair-side filters
TOTAL (A+B)	534	1,013	kg of mercury released TO WASTEWATER by offices per year

NOTES

*Except for dental clinics in hospitals

1. See dental offices' mercury usage page in this appendix.
2. Dentist use the appropriate spill size capsules, which contain enough amalgam to fill the cavity ("packing") plus extra amount to ensure enough amalgam to achieve proper finished restoration. This additional amount is called "overpack" and is discarded through the vacuum pump, down the cuspidor, or recovered as solid waste. The estimate that half of the mercury used per amalgam restoration may be released is from: Mary Joy Del Conte (1997) *A Mercury Pollution Prevention Study for Medical and Dental Centers,* Findings Report; Prepared for The Monroe County Mercury Pollution Prevention Task Force, Rochester, NY, page 12. Also, Bill Johnson, EIP Associates (2000); Technical Memorandum to Stephanie Hughes, Palo Alto Regional Water Quality Control Plan; Re: Mercury Amalgam Treatment Technologies for Dental Offices. The lower estimate has been suggested by dental association representatives at a meeting at the NY Academy of Sciences, on January 16, 2002.
3. See dental usage (mercury amalgams removed) for calculation of this range.
4. There are approximately 11,240 dentists in the watershed area (6,073 and 5,167 for NY and NJ counties respectively). There are 17,026 licensed and registered dentists in New York State, with 6,073 in the watershed area (Rita St. John, Professional, Licensing Services, Public Information Unit of NY State Education Department, personal communication, April 2001). There are approximately 10,000 dentists in NJ State (NJ Board of Dentistry, Licensing Board, May 2001); and about 5,167 dentists within the NJ watershed area (Grace Garcia, Division of Consumer Affairs, NJ; personal communication, April 23, 2001).
5. The estimate of dentists using mercury ranges from 70% to 83% of the total. Not all dentists use mercury, either because they are specialists (e.g. orthodontists) or they have already substituted for non-mercury amalgam. The Water Environmental Federation (1999) *Controlling Dental Facility Discharges in Wastewater: How to Develop and Administer a Source Control Program.* Also, NYC DEP (November 1999) *1998 Headworks Analysis Report*. For information on number of working days, and percentage of dentists using chairside and other filters.
6. Metropolitan Council Environmental Services and Minnesota Dental Association (December 2001) *Evaluation of Amalgam Removal Equipment and Dental Clinic Loadings to the Sanitary Sewer*, pg. 50.
7. Most reports, including those cited above, assume that dental offices operate for an average of 48 weeks, or 240 days, per year.

SUMMARY

	kg/yr*	Confidence Level
Calculation # 1	754	M/L
Calculation # 2	578	M/L
Average	**666**	**+/- 80**

Fluorescent Lamps—Usage (kg/yr)	
(Based on Estimated Range)	(Based on Confidence level)
650 +/- 100	**650 +/- 60%**

CALCULATION # 1

	13,000	kg of mercury in lamps sold in the U.S. in 1999[1]
x	5.8	% of the U.S. population living in the watershed area[3]
	754	kg of mercury in lamps sold in the watershed in 1999

CALCULATION # 2

	650,000,000	total fluorescent tubes and HID units sold in the U.S. per year[2]
	88	% are fluorescent tubes**
	8	% are compact fluorescent lamps**
	5	% are high intensity discharge (HID) lamps**
88%	572,000,000	fluorescent tubes sold in the US / year
x	5.8	% of the US population living in the NY/NJ Harbor watershed[3]
	33,176,000	fluorescent lamps sold in the watershed area
x	0.000013	kg of mercury per lamp of 4-feet lamps, on average (variable according to year of production)[4]
Subtotal A	431	kg of mercury used in fluorescent lamps in the watershed
8%	48,750,000	compact fluorescent lamps sold in the US / year[2]
x	5.8	% of the US population living in the NY/NJ Harbor watershed[3]
	2,827,500	compact fluorescent lamps sold in the watershed
x	0.000010	kg of mercury (minimum) per compact fluorescent[5]
Subtotal B	28	kg of mercury used in HID lamps in the watershed area
5%	29,250,000	HID lamps sold in the US / year
x	5.8	% of the US population living in the NY/NJ Harbor watershed[3]
	1,696,500	HID lamps are sold in the watershed per year
x	0.00007	kg of mercury on average per HID lamp[5]
Subtotal C	119	kg of mercury used in HID lamps in the watershed
Total (A+B+C)	**578**	kg of mercury in lamps sold in the watershed

NOTES

* The estimate for mercury in lamps represents only 50% of the mercury used by the Lighting Manufacturing Industry. The other 50% is used during the process of production, where it is recovered and sent to distillers for treatment and reuse. (NEMA)

** Due to rounding, reported percentages may not add to 100%

1. National Electrical Manufacturers Association, NEMA (2001) *Fluorescent Lamps and the Environment,* http://www.nema.org. This report states that Hg used by the lighting industry has decreased, from 57 tons in 1984 to 32 tons in 1997 and 13 tons in 1999. Fluorescent lamps manufactured in 1999 have only 13 mg of mercury on average.

2. Sustainable Conservation (2000), *Reducing Mercury Releases from Fluorescent Lamps: Analysis of Voluntary Approaches* http://www.suscon.org/reports

3. Census 2000; US population in 2000 was 285.3m. The population in the NY State area of the watershed is 10.4m and in NJ is 4.2m or a total of 5.2% of the US population. After adjusting by the level of disposable income, the estimate is 5.8% of the national population. http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc.gov/bea/regional/spi

4. NEMA (2001); *Fluorescent Lamps and the Environment;* http://www.nema.org. This report states that the current mercury content of a 4 foot fluorescent lamp ranges from 10 to 15 mg. Barr Engineering Company (2001) *Substance Flow Analysis of Mercury in Products* states that the average in 2000 was 13 mg per lamp. The average mercury content of fluorescent lamps in 1985 was 48.5 mg. Multiplying all fluorescent lamps by 13 mg is likely to underestimate the mercury in fluorescent tubes because 6' and 8' tubes have more mercury content.

5. http://www.ecy.wa.gov/programs/hwtr/demodebris/pages2/demolight/html.HIDLMP. A 75 KwH lamp contains 20 mg of mercury and a 1,000KwH contains 250mg. The average mercury content is estimated as about 70 mg per lamp; http://www.erendoe.gov/erec/factsheets/eelight.html

SUMMARY*

	kg/yr*	Confidence Level
Calculation # 1	593	M
Calculation # 2	832	M
Average	**712**	**+/- 120**

Fluorescent Lamps (kg/yr)	
(Based on Estimated Range)	(Based on Confidence level)
700 +/- 150	**700 +/- 50%**

CALCULATION # 1

	0.000018	kg per fluorescent tube discarded in 2001 (1996 production)[1]
x	31,517,200	fluorescent tubes sold in the watershed in 1996[2]
Subtotal A	567	kg of mercury released from discarded fluorescent tubes in the watershed
	0.000015	kg per compact fluorescent lamp discarded in 2001[3]
x	2,955,680	compact fluorescent lamps sold in watershed in 1996[4]
Subtotal B	44	kg of mercury released from discarded compact fluorescents in the watershed
	0.00007	kg per HID lamp discarded in 2001[3]
x	1,847,300	HID lamps sold in the watershed in 1996[5]
Subtotal C	129	kg of mercury discarded from HID lamps in the watershed today
Total(A+B+C)	741	kg of mercury available for release in the watershed (2001)
-	20	% of lamps recycled in watershed[7]
	593	kg of mercury released in watershed in year 2001

CALCULATION # 2

Overall releases from discarded lamps

	20,000	kg of mercury in fluorescent lamps disposed in US[8]
x	5.8	% of the US population living in the NY/NJ Harbor watershed[9]
	1,040	kg of mercury available for release in the watershed in 1999
-	20	% of lamps recycled in watershed[7]
	832	kg of mercury released in the watershed in 1999

NOTES

* Summary represents mercury in lamps discarded in the year 2001, which were produced five years prior. The industry mercury usage has decreased in the last decade (see Fluorescent Lamps Usage).

1. Mercury content in fluorescent lamps has declined, from 50 mg on average in 1985 to 23 mg in 1994 to 13 mg in 2000. Here we assume that the lamps being discarded in 2001 were produced at least five years before, around 1996. We use the average of 18 mg for this year, using the data from 1994 and 1999 reported in NEMA, Environmental Impact Analysis (2000), http://www.nema.org
2. Assuming the market for fluorescent lamps in the watershed was 95% of current market. Martha Bell, Association for Energy Affordability, NYC, pers. comm, October 2001.
3. www.ecy.gov/programs/hwtr/demodebris/pages2/demolight.html; This is an average mercury content for discarded lamps.
4. Assuming market for compact fluorescent lamps in the watershed was 98% of current market. Martha Bell, Association for Energy Affordability, NYC, pers. comm, October 2001.
5. Assuming market for HID lamps in the watershed was 98% of current market. Martha Bell, Association for Energy Affordability, NYC, pers. comm, October 2001.
6. Estimates for volatilization range from 20% to 80%. Here 25% is used. Barr Engineering Company (2001) *Substance Flow Analysis of Mercury in Products.* Proportions are reported on release distribution by pathway. Also, Michael Aucott, NJ DEP and NJ Mercury Task Group, personal communication.
7. The watershed recycling rate is assumed to be the same as the national rate of 20% given by Paul Ebernathy, Association of Lighting and Mercury Recyclers; personal communication 2-25-02. Brian Jantzen suggested that the regional recycling rate may be lower than the national rate, personal communication, April 2001.
8. Brian Jantzen (February 28, 2001); Testimony Before the Environmental Protection Committee of the NYC Council
9. Census 2000; US population in 2000 was 285.3 million. The population in the NY State area of the watershed is 10.4 million and in NJ is 4.2 million or a total of 5.2% of the US population. When this estimate is adjusted by the level of disposal income in the region, it rises to 5.8% of the national population. http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc.gov/bea/regional/spi/.

SUMMARY

	kg/yr*	Confidence Level
Calculation # 1	8,601	M
Calculation # 2	9,759	M/L
Average	**9,180**	**+/- 579**

Hospitals—Usage (kg/yr)	
(Based on Estimated Range)	(Based on Confidence level)
9,200 +/- 600	**9,200 +/- 60%**

CALCULATION # 1

Fever thermometers[2]

	0.0007	kg per thermometer[1]
x	1	unit per bed[2]
	0.0007	kg per bed
x	85,883	beds in 256 hospitals in the watershed[3]
Total	**60**	kg of mercury /yr (high turn around of inventory)

Sphygmomanometers[4]

	0.090	kg of mercury per sphygmomanometer[4]
x	1	unit per bed[5]
	0.090	kg of mercury per bed
Total x	85,883	beds in 256 hospitals in the watershed[3]
	7,729	kg of mercury in stock

Mercury in Products & Services	**(kg)**
Thermometers	60
Sphygmomanometers	7,729
Dental Clinics	95
Laboratories (in hospitals)	716
TOTAL	**8,601**

Dental Services:

Amalgam placement

	256	hospitals in the watershed[3]
x	56	% of the hospitals offer dental services[3]
	143	hospitals in the watershed offer dental services[3]
x	83	% of hospitals with dental facilities are likely to use mercury amalgams[6]
	119	hospitals in the watershed likely to use mercury amalgams
x	1,000	mercury amalgams restorations per hospital per year[7]
	118,989	mercury amalgams placed in watershed hospitals per year
x	0.0005	kg of mercury used per amalgam[7]
Sub-total A:	59	kg of mercury used per year in hospitals by the watershed

Amalgam removal

	1,000	amalgams removed per hospital per year[7]
x	143	hospitals in the watershed that offer dental services[3]
	143,360	amalgams removed in hospitals of the watershed (all clinics remove amalgams)
x	0.00025	kg of mercury becomes available during removal of old amalgam[8]
Sub-total B:	36	kg of mercury removed from old amalgams per year by hospitals in watershed
TOTAL (A+B):	**95**	kg of mercury used/generated per year by hospitals in the watershed

Laboratories:

		1,160	kg of mercury used in laboratories in watershed[9]
	/	705	total labs in watershed[10]
		2	kg of mercury used/yr/hospital laboratory
	x	235	hospitals with general clinical laboratory on site[3]
Sub-total A:		387	kg of mercury used/yr
		2	kg of mercury used/yr/hospital laboratory
	x	200	hospitals with a second lab within the facilities[3]
Sub-total B:		329	kg of mercury used/yr
	+		
TOTAL (A+B)		**716**	kg of hg used/ yr. in hospital laboratories in watershed

Other:

Other minor uses of mercury not accounted for here are gastrointestinal tubes (Cantor, Feeding tubes and Miller Abbot tubes, and Esophageal dilators); pharmaceutical supplies (Contact lens solutions, nasal spray and vaccines all containing Thimerosal, as well as diuretics and early pregnancy tests).[11] Batteries (button cell); fluorescent lamps; pressure gauges (barometers, manometers, vacuum gauges); thermostats and switches in hospitals are accounted for elsewhere in this document.

CALCULATION # 2

Factor	0.114	kg of mercury per hospital bed[12]
	85,883	hospital beds in watershed[1]
Total:	**9,759**	kg of mercury in hospitals of the watershed

NOTES

* Current estimate. As Hospitals substitute away from mercury products, the estimate will decrease.

1. Barr Engineering Co., *Substance Flow Analysis in Products* (2001), prepared for Minnesota Pollution Control Agency. Also, in http://www.state.in.us/idem/oppta/p2.
2. The number of mercury thermometers is variable, as many hospitals are replacing them with digital thermometers. The present estimate accounts only for the mercury thermometers that are unlikely to be replaced, such as those used for patients in neo-natal intensive care, and trauma or "burn" units. Strong Memorial Medical Center, Rochester University (750 beds) still uses an average of 60 thermometers a month (Pers.comm., Marvin Stillman, May 4,2001). A NYC hospital with over 1200 beds uses about 100 mercury thermometers per month (Pers. comm., Colleen Keegan, June 2001) while another hospital with over 800 beds reports that an average of 20 fever thermometers are discarded per week from neo-natal units. The estimated average is over 1 unit per bed. This figure does not account for mercury thermometers sent home with the patient. Each fever thermometers contains 0.7 grams of mercury (larger units contain 3 grams). Other thermometers that are not easily replaced are hypothermia type.
3. Information on hospitals per county and number of beds, laboratories and dental facilities within each hospital is from http://www.hospitalselect.com
4. MERC—Pollution Probe, November (1996) *Mercury in the Health Care Sector: The Cost of Alternative Products*. Also, Marvin Stillman, Strong Memorial Medical Center, University of Rochester, NY; personal communication (May 2001)
5. The number of sphygmomanometers was estimated to be 1 unit per bed based on an actual survey at New York Presbyterian Hospital, NY; data obtained by a blind hospital survey; and personal communication, Marvin Stillman (May 2001) and Colleen Keegan (June 2001). For example, a hospital in NYC with 550-beds had 401 mercury units (not including ambulatory services or clinics) and one in NY State with 750 beds disposed of 900 hg units during renovation (including those in ambulatory service and clinics). The average is 1 unit per bed with about 90 grams of mercury per unit.
6. NYC DEP (November 1999); 1998 Headworks Analysis report.
7. Metropolitan Council Environmental Services (1997). *Dental Clinic and Other Sources of Mercury to a WWTP* (Peter Berglund, P.E., MCES, St. Paul, MN). This survey of dentists in Minnesota, indicates that on average each dentist places 17.9 filings per week, and removes an average of 17.6 filings per week. The Metropolitan Area Water Environment Federation (1997) *Abstract from the Industrial Waste Technical Conference,* reports another survey of dentist conducted in Seattle, which indicates similar rates (17 and 16 / dentist/week). A typical hospital is assumed to place a *minimum* of 20 amalgams per week, or 960 per year, and remove a similar amount. The hospital clinics are assumed to work 50 weeks per year.
8. The Metropolitan Area Water Environment Federation (1997)
9. The regional estimate was derived from national inflows of mercury to laboratories, as reported on the USGS report (2000) *The Materials Flow of Mercury in the Economies of the U.S. and the World,* prepared by John L. Sznopek and Thomas Goonan. The national estimate was adjusted to regional demographics and by disposable level of income for the region (http://www.census.gov) and (http://www.bea.doc.gove/bea/regional/spi/). Based on this calculation the watershed region accounts for 5.8% of the total national population.
10. Information was compiled from CenStats (1997SIC Comparison) Zip Code Business Patterns at http://tier2.census.gov/cgi-win/zbp/compares.exe
11. From NYS DEC (2000) *A Pollution Prevention Guide to Reducing Mercury Emissions From Health Care Facility Incinerators*
12. Estimates of total use of mercury per hospital bed are from different regional surveys. They range from 0.25 pounds (http://www.epa.gov/glnpoocs/milwaukee-hg/mercuryr.pdf) to one pound of mercury per hospital bed (http://www.epa.gov/glnpo/bnsdocs/hgsbook/hospital.pdf). Taking the most conservative estimate then, (85,883 beds x 0.25lb)= 21,471 lbs. or 9,759 kg of mercury are used by hospitals in the watershed area.

Hospitals — *Mercury Available for Release*

SUMMARY

	kg/yr*	Confidence Level
Calculation # 1	1,366	L
	1,386	L
	1,376	**+/-10**

Hospitals -Hg Available for Release (kg/yr)	
Based on estimate range	(Based on confidence level)
1,400 +/-10	**1,400 +/- 70%**

CALCULATION #1

Thermometers

	85,883	hospital beds in watershed[1]
x	10	% of thermometers are assumed to break per year[2]
	8,588	broken thermometers per year in hospitals of the watershed
x	0.0007	kg per unit[3]
	6	kg/

Product/Service	kg/yr (range)		Recycled	
Thermometers	6	6	1	1
Sphygmomanometers	356	356	36	36
Dental Clinics	45	66	5	7
Laboratories	+ 1,002	1,002	0	0
Sub-total	1408	1430	42	44
Recycled	- 42	44		
Total	**1,366**	**1,386**		

Sphygmomanometers

	85,883	sphygmomanometers in all hospitals[4]
x	90	% wall-mounted units[5]
	77,295	wall-mounted units
x	4	% break per year[6]
	3,092	wall-mounted units break per year in hospitals of the watershed
x	0.09	kg of mercury per unit[7]
Sub-total A	278	kg of Hg spilled/yr. from broken wall-mounted sphygmomanometers
	85,883	sphygmomanometers in all hospitals[4]
x	10	% mobile units[5]
	8,588	mobile units in hospitals of the watershed
x	10	% of mobile units break per year[6]
	859	units break per year
x	0.09	kg of mercury per unit[7]
Sub-total B	77	kg of Hg spilled/yr. from broken mobile units
TOTAL (A+B)	**356**	kg of mercury spilled per year from broken sphygmomanometers in hospitals of the watershed

Distribution of initial releases by medium:[8]

Product/Service	To Air/Volatized	To Water	To Landfills	Recycled
Thermometers	10%	20%	60%	10%
Sphygmomanometers	10%	20%	60%	10%
Dental Clinics	N/A	25%	65%	10%
Laboratories	25%	70%	5%	0%

Dental Services

	Range		
	59	59	kg/yr of Hg used in hospitals' dental facilities[9]
x	15%	50	% of mercury used per amalgam may be released during placement[10]
	9	30	kg/yr available for release from placement of dental amalgam
+	36	36	kg/yr of mercury is released during removal of old amalgam[11]
TOTAL	**45**	**66**	kg/yr total available for release at hospitals' dental facilities

Laboratories

	28,000	kg of mercury outflow from U.S. laboratories per year[12]
x	5.8	% of the US population living in the NY/NJ Harbor watershed[13]
	1,624	kg of hg outflows from all labs in watershed
/	705	total labs in watershed[14]
	2.30	kg of mercury outflow/laboratory in the watershed/yr.
x	435	laboratories in hospitals in watershed[14]
	1,002	kg of hg outflows from hospital labs

NOTES

* Current level of releases. As Hospitals substitute away from mercury products, the estimate will decrease.

1. See calculation on page for hospitals' *mercury usage.*
2. The report from Barr Engineering Co. (August 2001) *Substance Flow Analysis of Mercury in Products* estimates that the rate of broken thermometers may be as high as 50%. However, personal communication (May 2001) with various hospital representatives, indicated that training may have brought that rate down considerably to 10%. The latter, more conservative estimate, is assumed here.
3. Barr Engineering Co. (2001) *Substance Flow Analysis in Products* prepared for Minnesota Pollution Control Agency. Also, in http://www.state.in.us/idem/oppta/p2
4. The number of sphygmomanometers was estimated to be 1 unit per bed based on an actual survey at New York Presbyterian Hospital, NY; data obtained by a blind hospital survey; and personal communication, Marvin Stillman (May 2001) and Colleen Keegan (June 2001). For example, a hospital in NYC with 550-beds had 401 mercury units (not including ambulatory services or clinics) and one in NY State with 750 beds disposed of 900 hg units during renovation (including those in ambulatory service and clinics). The average is 1 unit per bed with about 90 grams of mercury per unit.
5. Survey information and Gregory Camacho, Hospital Risk Manager, NY Presbyterian Hospital; Pers. Comm. (September 2001).
6. Barr Engineering, Co. (2001) and also, Marvin Stillman, Strong Memorial Medical Center, University of Rochester, NY.; personal communication (May 2001) as well as Gregory Camacho, Hospital Risk Manager, NY Presbyterian Hospital (September 2001).
7. MERC- Pollution Probe (November 1996) *Mercury in the Health Care Sector: The Cost of Alternative Products.*
8. Barr Engineering Co. (2001) reports on distribution from broken thermometers. We assume the same distribution rate for sphygmomanometers. For dental releases, see dental sector. For laboratories, see Laboratory sector. Estimate confirmed by Gregory Camacho, Hospital Risk Manager, NY Presbyterian. Personal communication, (September 2001).
9. See page on hospitals' *mercury* usage in this appendix.
10. For the higher estimate see: Mary Joy Del Conte (1997) *A Mercury Pollution Prevention Study for Medical and Dental Centers,* Findings Report; prepared for The Monroe County Mercury Pollution Prevention Task Force, Rochester, NY. The lower estimate has been suggested by dental sector representatives at a NYC DEP CAC meeting in January 2002.
11. See page on hospitals' *mercury* usage
12. Regional estimate derived from national outflows of mercury to laboratories (28 tons/yr), as reported in Sznopek and Goonan (2000) *The Materials Flow of Mercury in the Economies of the U.S. and the World,* pg. 7.
13. Census 2000; US population in 2000 was 285.3 million. The population in the NY State area of the watershed is 10.4 million and in NJ is 4.2 million or a total of 5.2% of the US population. When this estimate is adjusted by the level of disposal income in the region, it rises to 5.8% of the national population. http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc.gov/bea/regional/spi/.
14. http://www.hospitalselect.com

Households Sector: Residential Furnaces — *Mercury Usage*

SUMMARY

No intentional usage of mercury in households from combination processes
Only incidental releases

Households Sector: Residential Furnaces — *Mercury Available for Release*

SUMMARY

	kg/yr	Confidence Level
Calculation # 1	**160**	**M**

Households—(kg/yr)
(Based on Confidence level)
150 +/-50%

CALCULATION # 1

Emissions from residential furnaces:

	80	kg of mercury emitted in 1998 from residential furnaces in NJ[1]
+	200	kg of mercury emitted in 1998 from residential furnaces in NY[1]
	280	kg of mercury emitted in both states by utilities
	57	% population of watershed region with respect to both states' population[1]
	160	kg of mercury emitted in 1998 in the watershed by utilities

NOTES

1. Nickolas J. Themelis and Alexander F. Gregory (2001) *Sources and Material Balance of Mercury in the NY/NJ Harbor,* report to the New York Academy of Sciences, October 3, 2001.

Household Sector: Thermometers — *Mercury Usage*

SUMMARY

	kg/yr	Confidence level
Calculation # 1	**969**	**M/L**

Thermometers—(kg/yr)
(Based on Confidence level)
1,000 +/- 60%

CALCULATION # 1

0.24	thermometers sold per household in the watershed per year[1]
5,769,258	households in the watershed[2]
1,384,622	thermometers sold in the watershed per year
0.70	kg per fever thermometer[3]
969	kg of mercury in thermometers sold in the watershed per year

NOTES

1. Extrapolated from data for the state of Minnesota; Barr Engineering Co. (2001) *Substance Flow Analysis in Products* prepared for the Minnesota Pollution Control Agency.
2. http:www.census.gov. There are 7,056,860 households in New York and 3,064,645 in New Jersey; the population of the watershed represents 57% of the total for both states.
3. http://www.state.in.us/idem/oppta/p2

Household Sector: Thermometers — *Mercury Available for Release*

SUMMARY

	kg/yr	Confidence level
Calculation # 1	**485**	**M/L**

Thermometers (kg/yr)
(Based on Confidence level)
500 +/- 60%

CALCULATION # 1

	1,384,622	thermometers are sold in the watershed region per year[1]
x	50	% of sold thermometers replace broken thermometers[2]
	692,311	broken units in the watershed, approximately
x	0.0007	kg per fever thermometer[3]
	485	kg of mercury released per year by households in the watershed region

NOTES

1. From page on thermometers (mercury usage)
2. Follows assumption by Barr Engineering Co. (2001) *Substance Flow Analysis in Products* that at least half of the sold thermometers replace broken units
3. http://www.state.in.us/idem/oppta/p2

Households Sector: Wastewater* — *Mercury Usage*

SUMMARY

No intentional usage of mercury in households (except thermometers)
Only incidental releases

Households Sector: Wastewater* — *Mercury Available for Release*

SUMMARY

	kg/yr	Confidence Level
Calculation # 1	**360**	**M**

Households (kg/yr)

350 +/- 50%
250 +/- 50%
(minus 100 kg coming from broken thermometers and accounted for in that section)

CALCULATION # 1

	1,400,000,000	gallons discharged at NYC WWTPs per day[1]
x	365	days /yr
	511,000,000,000	gallons per year
x	75	% from households[2]
	383,250,000,000	gallons from households, per year
x	3.8	liters per gallon
	1,456,350,000,000	liters from NYC households per year
x	0.000000138	g/L, average mercury concentration of discharge from households in NYC[3]
	201	kg of mercury discharged per year from households
/	8,008,276	people in NYC[4]
	25.1E-6	kg of mercury discharged in household wastewater per person
x	14,327,871	population in the watershed[4]
	360	kg of mercury discharged in wastewater per year from households in the watershed

NOTES

* Association of Metropolitan Sewerage Agencies (August 2000); "Evaluation of Domestic Sources of Mercury" offers a complete list of mercury containing products found in households.

1. NYC DEP, Philip Heckler, Deputy Director, Environmental Affairs, Bureau of Wastewater Treatment; personal communication, October 2001. and NYC DEP (November 1999); 1998 Headworks Analysis Report.
2. NYC DEP (November 1999); *1998 Headworks Analysis Report.*
3. Ibid
4. Census 2000; http://www.census.gov/population/www/estimates/statepop.html.

Industrial and Commercial Furnaces *Mercury Usage*

SUMMARY

No intentional usage of mercury from combustion processes in industrial and commercial furnaces
Only incidental releases

Industrial and Commercial Furnaces Mercury Available for Release

SUMMARY

	kg/yr	Confidence Level
Calculation # 1	**330**	**M**

Indust/Comm. Furnaces (kg/yr)
(Based on Confidence level)
350 +/-50%

CALCULATION #1

	79	kg of mercury emitted in 1998 from industrial and commercial furnaces in NJ[1]
+	500	kg of mercury emitted in 1998 from industrial and commercial furnaces in NY[1]
	579	kg of mercury emitted in both states by utilities
	57	% population of watershed region with respect to both states' population[1]
	330	kg of mercury emitted in 1998 in the watershed by utilities

NOTES

1. Nickolas J. Themelis and Alexander F. Gregory (2001) *Sources and Material Balance of Mercury in the NY/NJ Harbor.* Report to the New York Academy of Sciences, October 3, 2001.

Laboratories (excl. hospitals labs) — *Mercury Usage*

SUMMARY

	kg/yr	Confidence Level
Calculation # 1	**444**	**L**

Laboratories (kg/yr)
(Based on Confidence level)
450 +/- 70%

CALCULATION #1

	20,000	kg of mercury used in laboratories in the US[1]
x	5.8%	of the U.S. population lives in the watershed[2]
	1,160	kg of mercury used in all laboratories in watershed[2]
/	705	laboratories in watershed[3]
	1.65	kg of mercury used/laboratory
x	270	total labs in watershed[3] (not in hospitals)[4]
	444	kg of hg used per year per laboratory in watershed, on average

NOTES

1. Sznopek and Goonan, *The Materials Flow of Mercury in the Economies of the U.S. and the World,* p.7.
2. Regional estimate derived from national inflows of mercury to laboratories (20 tons/yr), as reported on USGS (2000). The national estimate was adjusted to regional demographics and by the level of disposable income for the region (http://www.census.gov) and (http://www.bea.doc.gove/bea/regional/spi/). Based on this calculation the watershed region accounts for 5.8% of the total national population.
3. Information was compiled from CenStats (1997SIC Comparison) Zip Code Business Patterns at http://tier2.census.gov/cgi-win/zbp/compares.exe
4. Information on hospitals per county and number of beds, laboratories and dental facilities within each hospital is from http://www.hospitalselect.com

Laboratories (excl. hospitals labs) — *Mercury Available for Release*

SUMMARY

	kg/yr	Confidence level
Calculation # 1	**622**	**L**

Laboratories (kg/yr)
(Based on Confidence level)
600 +/- 70%

CALCULATION # 1

	28,000	kg of hg outflows per year from all laboratories in the US[1]
x	5.8	% of the U.S. population lives in the watershed[2]
	1,624	kg of hg outflows from all labs in watershed[2]
/	705	total labs in watershed[3]
	2.3	kg of mercury per lab[4]
x	270	labs in the watershed (not in hospitals)
	622	kg of mercury from labs (not in hospitals) per year

NOTES

1. USGS (2000) *The Materials Flow of Mercury in the Economies of the U.S. and the World* prepared by Sznopek and Goonan, p. 7. This report states indicates that 28 tons of mercury flow out per year from laboratories in the US, more than yearly inflows, due to inventories.
2. Regional estimate derived from national outflows of mercury to laboratories (28 tons/yr), as reported on USGS (2000). The national estimate was adjusted to regional demographics and by the level of disposable income for the region (http://www.census.gov) and (http://www.bea.doc.gove/bea/regional/spi/). Based on this calculation the watershed region accounts for 5.8% of the total national population.
3. Information was compiled from CenStats (1997SIC Comparison) Zip Code Business Patterns at http://tier2.census.gov/cgi-win/zbp/compares.exe
4. USGS (2000) p. 21. Two-thirds of the mercury in laboratories is used for reagents and catalysts, which may end up in the wastewater. This report states that, nationally, 90% is recycled. However, Carl Plossl from EPA, Region 2, Compliance Department stated that this is not the case in the watershed region, where recycling is minimum. Personal communication, October 2001.

Switches—Lighting *Mercury Usage*

SUMMARY

	kg/yr	Confidence level
Calculation # 1	**6,844**	**M/L**

Lighting Switches (kg/yr)
(Based on Confidence level)
7,000 +/- 60%

CALCULATION # 1

118,000 kg of mercury in use in lighting switches in the US[1]
x 5.8 % of the US population in the watershed region[2]
6,844 kg of mercury in lighting switches used in the watershed

NOTES

1. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District, (1997) *Mercury Source Sector Assessment for the Greater Milwaukee Area*
2. Census 2000; http://www.census.gov/population/www/estimates/statepop. The population of the watershed area represents over 5.2% of the national population. When this is adjusted by the level of disposable income of the region, this estimate rises to 5.8% of the national population. http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc.gov/bea/regional/spi

Switches - Lighting *Mercury Available for Release*

SUMMARY

	kg/yr	Confidence level
Calculation # 1	**112**	**M/L**

Appliance Switches (kg/yr)
(Based on Confidence level)
100 +/- 60%

CALCULATION # 1

1,930 kg of mercury in lighting switches disposed per year in the US[1]
x 5.8 % of the US population in the watershed region[2]
112 kg of mercury in lighting switches disposed per year in the watershed

NOTES

1. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997) *Mercury Source Sector Assessment for the Greater Milwaukee Area.*
2. Census 2000; http://www.census.gov/population/www/estimates/statepop. The population of the watershed area represents over 5.2% of the national population. When this is adjusted by the level of disposable income of the region, this estimate rises to 5.8% of the national population.http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc.gov/bea/regional/spi

Switches—Appliances *Mercury Usage*

SUMMARY

	kg	Confidence level
Calculation # 1	**1,352**	**M/L**

Appliance Switches (kg/yr)
(Based on Confidence level)
1,400 +/- 60%

CALCULATION # 1

	5,769,258	households in the watershed[1]
x	0.43	freezers per household[2]
	2,480,781	freezers in watershed
x	50	% of freezers are chest units containing mercury switches[2]
	1,240,390	freezers in watershed containing mercury switches
x	0.001	kg of Hg per switch[2]
Subtotal A	1,240	kg of mercury in chest freezers in the watershed
	480,000	gas-pilot ranges in use in the U.S. (non-electric)[2]
x	5.8	% of US population living in the watershed[3]
	27,840	gas-pilot ranges sold in the watershed in year 2000
x	0.004	kg of Hg per switch[2]
Subtotal B	111	kg of mercury in gas-pilot ranges use in the watershed
Total (A+B)	**1,352**	kg of mercury in appliances used in the watershed

Other: This calculation does not include washing machines because the last models that used mercury switches were manufactured prior to 1972, and it is assumed that they all are retired. Some appliances may contain fluorescent lamps to illuminate control panels.

NOTES

1. http:www.census.gov. (2000) There are 7,056,860 households in New York (of which about 54% are in the watershed) and 3,064,645 in New Jersey (of which over 49% are in the watershed).
2. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997); *Mercury Source Sector Assessment for the Greater Milwaukee Area.*
3. Census 2000; US population in 2000 was 285.3 million. The population in the NY State area of the watershed is 10.4 million and in NJ is 4.2 million or a total of 5.2% of the US population. After adjusting it by the level of disposable income, the estimate is 5.8% of the national population. http://www.bea.doc.gov/bea/regional/spi/ and http://www.census.gov/population/www/estimates/statepop.html
4. Appliance Recycling Information Center (January 2002); *InfoBulletin # 8: Mercury in Home Appliances*

Switches—Appliances *Mercury Available for Release*

SUMMARY

	kg	Confidence level
Calculation # 1	**28**	**L**

Appliance Switches (kg/yr)
(Based on Confidence level)
25 +/- 70%

CALCULATION # 1

	5,769,258	households in the watershed[1]
x	0.35	appliances discarded per household per year[2]
	2,019,240	appliances discarded in the watershed per year[2]
x	0.01	mercury switches per appliance[2]
	20,192	mercury switches discarded in switches in the watershed[2]
x	0.001	kg of mercury per appliance[2]
	28	kg of mercury in appliances disposed in the watershed per year

NOTES

1. Census 2000; http://www.census.gov/population/www/estimates/statepop. The NY State population in the watershed area is 10.4M and in NJ is about 4.2M. There are approximately 5.8M households in the watershed region.
2. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997) *Mercury Source Sector Assessment for the Greater Milwaukee Area.* This rate includes all types of appliances. Only washers, chest freezers and gas pilot ranges have mercury switches.

SUMMARY

	kg	Confidence level
Calculation # 1	7,445	M
Calculation # 2	9,976	M/L
	11,600	M/L
Average	**9,674**	**+/- 2,094**

Switches - Automobiles (kg/yr)	
(Based on Estimated Range)	(Based on Confidence level)
9,700 +/- 2,100	**9,700 +/- 60%**

CALCULATION # 1

	4,590,000	registered cars in NY watershed region[1]
+	2,854,740	registered cars in NJ watershed region[2]
	7,444,740	total number of registered cars in watershed
x	1	switch per vehicle, on average[3]
	7,444,740	number of switches in cars in watershed
x	0.001	kg of mercury per switch[4]
	7,445	kg of mercury used in car switches in the watershed

CALCULATION # 2

	Range		
	172,000	200,000	kg of mercury in vehicles on the road in the US[5]
x	5.8 %	5.8	% of US population living in the watershed
	9,976	**11,600**	kg of mercury in vehicles on the road in the watershed

NOTES

1. Census 2000; http://www.census.gov/population/www/estimates/statepop. New York State population in 2000 was 18,976,457. The NY State population in the watershed area is 10.4 million, or almost 54% of the state population. There are approximately 8.5 million registered cars in New York state (http://www.albany.net/~gra/newsltrs.1998/nov98.htm) of which 54% is assigned to the watershed area.
2. Census 2000; http://www.census.gov/population/www/estimates/statepop.html. The population in the NJ State in 2000 was 8,414,350 and for the watershed 4.2 million. This represents about 49% of the state population. There are 5,826,000 registered cars in the state of New Jersey (http://www.bergen.com/special/autos/19400611.htm), of which 49% is assigned to the watershed area.
3. Although not all cars have mercury switches, certain models have one light switch in the trunk and another in the hood, with 1 gram each. In addition, most sport utility vehicles (SUVs) have one or two anti-lock brake sensor systems with 3 or 4 switches each, for a total of 3 or 4 grams each system. A recent PBC News report (10/9/01) indicated that about 46% of US vehicles are SUVs. Personal Communication 10/10/01, Tom Corbett (NYS DEC, Mercury Reduction Program). The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997) *Mercury Source Sector Assessment for the Greater Milwaukee Area* indicates that the ratio ranges between 43% of mercury switches per car (trunk and hood only), to 1.06 mercury switches per vehicle.
4. NYS DEC Mercury Reduction Program, personal communication with Tom Corbett (October 2001).
5. Charles Griffith, Jeff Gearhart and Hans Posset (January 2001) *Toxics in Vehicles: Mercury—Implications for Recycling and Disposal.*

Switches—Automotive* *Available for Release*

SUMMARY

	kg	Confidence level
Calculation #1	700	M
Calculation # 2	837	M/L
Calculation # 3	938	L
	1,090	L
Average	**891**	**+/- 165**

Switches Automobiles (kg/yr)	
(Based on Estimated Range)	(Based on Confidence level)
900 +/- 200	**900 +/- 70%**

CALCULATION # 1

	7,444,740	total number of registered cars in watershed[1]
x	10%	annual percentage cars disposed at end of life[2]
	744,474	cars disposed of in the watershed per year
x	1	switch per car, on average[3]
	744,474	switches disposed of in the watershed per year
x	0.001	kg of mercury per switch[4]
	744	available for release per year
-	45	kg/yr recycled (assuming a 6% annual rate)[5]
	700	kg/yr released in the watershed

CALCULATION # 2

	12,000,000	vehicles retired per year in US[6]
x	5.8%	of US population living in the watershed[7]
	696,000	vehicles retired per year in the watershed
	1.6	switch per car, on average[6]
	1,113,600	switches disposed in watershed area
x	0.001	kg of mercury per switch[4]
	891	available for release per year
-	53	kg/yr recycled (assuming a 6% annual rate)[5]
	837	kg/yr released in the watershed

CALCULATION # 3

	Range		
	9,976	11,600	kg of mercury in vehichles on the road in watershed[8]
x	10 %	10 %	annual percentage cars disposed at end of life[2]
	998	1,160	kg of mercury disposed in vehicles in the watershed
-	60	70	kg/yr recycled (assuming a 6% annual rate)[5]
	938	**1,090**	kg/yr released in the watershed

NOTES

*Mercury switches have been slowly phased out of automobiles over the last 5-10 years and will not longer be used in 2003 car models.

1. See estimate in mercury usage page for switches - automotive sector
2. Tom Corbett, NYS DEC, Mercury Reduction Program, personal communication (10/10/01).
3. Although not all cars have mercury switches, certain models have one light switch in the trunk and another in the hood, with 1 gram each. In addition, most sport utility vehicles (SUVs) have one or two anti-lock brake systems with 3 or 4 switches each, for a total of 3 or 4 grams each system. A recent PBC report (10/9/01) indicated that almost half the fleet of cars sold consists of SUVs . Personnal Communication 10/10/01, Tom Corbett (NYS DEC, Mercury Reduction Program). The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997); *Mercury Source Sector Assessment for the Greater Milwaukee Area* indicates that the ratio ranges between 43% of mercury switches per car (trunk and hood only), to 1.06 mercury switches per vehicle.
4. NYS DEC Mercury Reduction Program, personal communication
5. Barr Engineering Co. (2001) *Substance Flow Analysis of Mercury in Products.* Similar estimate gathered at visit to shredder facility in Long Island City, NY (Spring 01).
6. Charles Griffith, Jeff Gearhart and Hans Posset (January 2001) *Toxics in Vehicles: Mercury—Implications for Recycling and Disposal.*
7. Census 2000; http://www.census.gov/population/www/estimates/statepop. The population of the watershed area represents over 5.2% of the national population. When this is adjusted by the level of disposable income of the region, this estimate rises to 5.8% of the national population.
8. Griffith et al. (January 2001)

Thermostats *Mercury Usage*

SUMMARY

	kg/yr	Confidence Level
Calculation # 1	870	M/L
	1,856	M/L
Average	**1,363**	**+/- 697**

Thermostats (kg/yr)	
Based on Estimated Range	(Based on Confidence level)
1,400 +/- 700	**1,400 +/- 60%**

CALCULATION # 1

	Range		
	5,000,000	8,000,000	mercury switches in thermostats sold in the US per year[1]
x	5.8 %	5.8	% of the US population living in the NY/NJ Harbor watershed[2]
	290,000	464,000	thermostats sold in the watershed area per year
x	0.003	0.004	kg of mercury per thermostats[3]
	870	**1,856**	kg of mercury sold in thermostats in the watershed per year

NOTES

1. John Reindl indicated about 5 million thermostats are sold in the U.S. per year; personal communication (June 2001). The estimate of 8 million mercury switches for thermostats sold annually in the U.S. is from http://aesop.rutgers.edu/~wastemgmt/MEETINGS/meeting2.htm
2. Census 2000; US population in 2000 was 285.3 million. The population in the NY State area of the watershed is 10.4 million and in NJ is 4.2 million or a total of 5.2% of the US population. When adjusted to the level of disposable income, this region represents 5.8% of the national population. http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc.gove/bea/regional/spi/
3. Amount contained in new thermostat units (3 grams) as reported in http:www.nema.org; there are 4 grams of mercury in the average thermostat, as reported in http://aesop.rutgers.edu/~wastemgmt/METTINGS/meeting2.htm

Thermostats — *Mercury Available for Release*

SUMMARY

	kg	Confidence Level
Calculation # 1	**597**	**M/L**

Thermostats (kg/yr)
(Based on Confidence level)
600 +/- 60%

CALCULATION #1

Releases		2,619,000	thermostats disposed of in the US per year, on average[1]
	x	5.8	% of the US population living in the NY/NJ Harbor watershed[2]
		151,902	thermostats disposed of in the watershed per year
	x	0.004	kg per old units currently being discarded[3]
		607	kg of mercury in units currently discharged
	–	10	kg of mercury recycled for the Watershed per year[4]
		597	kg of mercury in thermostats, available for release in watershed region/yr

NOTES

1. The Pollution Prevention Partnership and the Milwaukee Metropolitan Sewerage District (1997) *Mercury Source Sector Assessment for the Greater Milwaukee Area.* This estimate represents thermostats discarded at end of life (20 years) or during renovation.
2. Census 2000 http://www.census.gov/population/www/estimates/statepop.html and http://www.bea.doc.gove/bea/regional/spi/
3. http://www.nema.org. Thermostats discarded today have more mercury than units currently produced.
4. Thermostat Recycling Corporation (1999); Wholesaler Questions and Answers to the Mercury Thermostat Recycling Program; http://www.nema.org/government/environmental

Utilities: Furnaces — *Mercury Usage*

SUMMARY

No intentional usage of mercury in utilities - furnaces' combustion process
Only incidental releases

Utilities: Furnaces — *Mercury Available for Release*

SUMMARY

	kg	Confidence level
Calculation # 1	**384**	**M**

Utilities: Furnaces (kg/yr)
(Based on Confidence level)
400 +/- 70%

CALCULATION # 1

	186	kg of mercury emitted in 1998 from utilities in NJ[1]
+	487	kg of mercury emitted in 1998 from utilities in NY[1]
	673	kg of mercury emitted in both states by utilities
x	57	% population of watershed region with respect to both states' population[1]
	384	kg of mercury emitted in 1998 in the watershed by utilities

NOTES

1. Nickolas J. Themelis and Alexander F. Gregory (2001) *Sources and Material Balance of Mercury in the NY/NJ Harbor.* Report to the New York Academy of Sciences, October 3, 2001.

6.3 Cost of Pollution Prevention and Management Measures

Crematoria ***Costs/Net Savings***

SUMMARY

Cost Range for Installing Selenium Filter Systems at Crematoria			kg of Hg/yr	Cost per kg	
$9,000,000	$9,000,000	equipment cost			
$270,000	$360,000	annual operating costs	25	$10,800	$14,400
$2,465,016	$2,555,016	Total cost assuming 5-yr loan	25	$98,601	$102,201

CALCULATION # 1

Selenium Filter System

Equipment costs

		45	crematoria in the watershed area (servicing 430 cemeteries)[1]
	x	$200,000	cost of installing selenium filters system, per crematorium[2]
Sub-total A		$9,000,000	cost of installing filter systems at all crematoria in the watershed
or:		$2,195,016	per year, based on a 5-year loan (constant payment plan at 7% interest rate)

Operating costs

		Range		
		600	800	cremations per crematorium per year[3]
	x	45	45	crematoria in the watershed area
		27,000	36,000	cremations per year
	x	$10	$10	per cremation in operating expenses[2]
Sub-total B		$270,000	$360,000	in operating expenses for all crematoria in the watershed, per year
Total (A+B)		$2,465,016		per year for five years (assuming 5 year loan at 7% interest was secured)
		$270,000	$360,000	range of costs per year after five years

NOTES

1. Information was compiled from CenStats (1997SIC Comparison) Zip Code Business Patterns at http://tier2.census.gov/cgi-win/zbp/compares
2. Information on cost to install selenium filter systems and operating cost per cremation by amalgator@worldonline.nl (Vermeulen Deventer)
3. http://www.nfda.org/resources/deathstats.html

Dental Offices — Cost/Net Savings

SUMMARY

Total Cost to use amalgams and prevent Hg releases

First year	Range		Kg of Hg/yr		Cost range/kg of Mercury	
Cost of amalgam materials	$2,643,648	$3,806,314	3,600		$734	$1,057
Cost of recycling solid waste	$659,400	$781,860	3,000		$220	$261
Cost of filtration -1st yr	+ $10,008,750	$10,990,000	1,000		+ $10,009	$10,990
Total:	**$13,311,798**	**$15,578,174**		Total:	**$10,963**	**$12,308**

Per year after first	Range		Kg of Hg/yr		Cost range/kg of Mercury	
Cost of amalgam materials	$2,643,648	$3,806,314	3,600		$734	$1,057
Cost of recycling solid waste	$659,400	$781,860	3,000		$220	$261
Cost of filtration -after 1st yr	+ $2,983,000	$9,420,000	1,000		+ $2,983	$9,420
Total:	**$6,286,048**	**$14,008,174**		Total:	**$3,937**	**$10,738**

Total Cost to use non-mercury composites and prevent Hg releases from amalgam removal

First year	Range		Kg of Hg/yr		Cost range/kg of Mercury	
Cost of composite materials	$12,160,781	$17,509,043	3,600		$3,378	$4,864
Cost of recycling	$659,400	$781,860	2,100		$314	$372
Cost of filtration	+ $10,008,750	$10,990,000	700		+ $14,298	$15,700
Total:	**$22,828,931**	**$29,280,903**		Total:	**$17,990**	**$20,936**

Per year after first	Range		Kg of Hg/yr		Cost range/kg of Mercury	
Cost of amalgam materials	$12,160,781	$17,509,043	3,600		$3,378	$4,864
Cost of recycling solid waste	$659,400	$781,860	2,100		$314	$372
Cost of filtration -after 1st yr	+ $2,983,000	$9,420,000	700		+ $4,261	$13,457
Total:	**$15,803,181**	**$27,710,903**		Total:	**$7,953**	**$18,693**

CALCULATION # 1: COST OF AMALGAM MATERIAL

Dental Sector's annual cost for using amalgam (materials only)

	Range		
	11,240	11,240	dentists in the watershed[1]
x	70 %	83	% percentage of dentists performing restorations and using mercury amalgams[2]
	7,868	9,329	dentists in watershed using mercury
x	672	816	amalgams per dental office per year[3]
	5,287,296	7,612,627	amalgams per year applied by dentists in the watershed
x	$0.50	$0.50	average cost per mercury amalgam (material only)[4]
	$2,643,648	**$3,806,314**	cost of mercury amalgam material per year for all dentists in the region

CALCULATION # 2: COST OF RECYCLING SOLID WASTE

Cost to recycle all solid waste containing amalgam in the watershed:

	Range		
	7,850	7,850	dental offices in the watershed (some dentists share offices)[5]
x	$120	$120	recycling cost per year of solid waste (3 times yearly at $40/shipment)[6]
	$942,000	$942,000	cost of comprehensive recycling per year in the region
x	70 %	83	% dentists using mercury amalgam[2]
	$659,400	**$781,860**	annual cost of recycling all solid waste containing amalgam by all dentists in region

CALCULATION # 3: COST OF FILTER SYSTEMS FOR WASTEWATER DISCHARGES

A: In-house management of filter system

Equipment purchase and installation

	$695	Cost of separator filter system (one-time expenditure)[7]
+	$200	Installation fee (one-time expenditure)[7]
	$895	Total cost of installing filter system per dental office (1-time)
x	7,850	dental offices in the watershed[5]
Subtotal A	7,025,750	Total costs of installing filter systems in all dental offices in region (1-time fee)

Operating costs of filtration systems

	$150	cost per filter cartridges[7]
x	2	filters per year[7]
	$300	total costs for filter cartridges/dental office/yr.
+	$80	cost to recycle filters directly by dentists ($40 for shipping, twice yearly)[7]
	$380	Cost for filters and recycling per office
x	7,850	dental offices in the watershed using mercury amalgam
Subtotal B	$2,983,000	yearly cost for filters and recycling in the watershed
TOTAL (A+B)	**$10,008,750**	cost for operating filter systems in region for first year
or	$2,983,000	cost per year after first year

B: Outside service managing filtration system

Full service: dentists do not assume liability for managing Hg waste

First year

	$200	Installation of separator filter system[8]
+	$1,200	Cost of full service/yr (replacement & disposal of filters). Equipment fee is waived[8]
	$1,400	Total cost for first year per dental office
x	7,850	dental offices in the watershed using mercury amalgam[5]
	$10,990,000	Total cost of using filter system service for first year, all dentists in region

Each subsequent year

	$1,200	Cost of full service per year (replacement & disposal of filters). Equipment fee is waived[8]
x	7,850	dental offices in the watershed using mercury amalgam[5]
	$9,420,000	Total cost per year after 1st year for all dentists in watershed

CALCULATION # 4: SUBSTITUTION

Cost of materials for all dentist substituting for non-mercury composite (materials only)

	Range		
	11,240	11,240	dentists in the watershed[1]
x	70 %	83 %	percentage of dentists performing restorations (if all substitute for non-Hg composite)[2]
	7,868	9,329	dentists in watershed performing restorations
x	672	816	restorations per dental office per year[3]
	5,287,296	7,612,627	restorations per year performed by dentists in the watershed
x	$2.3	$2.3	average cost per composite resin (material only)[4]
	$12,160,781	**$17,509,043**	cost of mercury amalgam material per year for all dentists in the region

NOTES

1. See Appendix 6.2 - Dental sector mercury usage
2. Not all dentists use mercury, either because they are specialists (e.g. orthodontists) or they have already substituted for non-mercury amalgam. It is estimated that 70% to 83% use and/or remove mercury amalgams. Environmental Federation (1999) *Controlling Dental Facility Discharges in Wastewater: How to Develop and Administer a Source Control Program.* Also, NYC DEP (November 1999); 1998 Headworks Analysis Report.
3. A survey of dentists by a POTW in Minnesota, indicates that the average rate of placing fillings is 17.9 per week per general dentist, and 17.6 removed fillings on average per dentist per week. Another estimate indicates that the rate of amalgam placement for all dentists is 14 restorations per week since specialists (e.g., orthodontists) are not involved in amalgam restorations. Information from: Metropolitan Council Environmental Services (1997) *Dental Clinic and Other Sources of Mercury to a WWTP* (Peter Berglund, P.E., MCES, St. Paul, MN) . Another report in Seattle indicates similar rates (17 removed and 16 placed / dentist/week). The Water Environment Federation (1999) *Controlling Dental Facility Discharges in Wastewater: How to Develop and Administer a Source Control Program* (WEF, Alexandria, VA)
4. The single spill capsule contains approximately 300 mg of mercury and costs about $0.43; a double spill capsule contains almost 500 mg, and costs is $0.52 each, while the triple spill capsule contains about 600 mg of mercury and costs about $0.64. The average per amalgam restoration is 500 mg of mercury. The average price is $0.508. Prices for mercury capsules (Henry Schein Alloys) are for purchases in bulk. Prices for the (Charisma Heraeus Kulser) resin composite for both anterior and posterior restorations are based on syringe refills. All prices are reported on http://www.sullivanschein.com and are similar to other dental catalogues (Dentsply-Caulk and Kerr).
5. Data on number of dental offices per county was compiled from http://www.census.gov/epcd/cbp/map/99data/34/003.txt (New Jersey) and http://www.census.gov/epcd/cbp/map/99data/36/005.txt (New York)
6. Assumes mercury is shipped to retorting facility directly by common carrier at a cost of $40 per up to 30 lbs, per shipment. NY and NJ accept the RCRA code for mercury permitting such shipments.
7. Owen Boyd, SolmeteX Co. that sells separator filters; personal communication, July 2001.
8. Marc Sussman, Dental Recycling of North America, personal communication, July 2001

SUMMARY

Costs Range for using fluorescent lamps:

				kg of Hg recycled/yr	Cost/kg of Hg
	$153,182,640	$967,970,120	Cost of purchasing fluorescent lamps per year		
+	$24,226,020	$24,226,020	Cost of recycling all fluorescent lamps per year	700	$34,609
Total Cost	**$177,408,660**	**$992,196,140**			

Savings **$1,008,562,464** Energy cost savings from puchasing fluorescent rather than incandescent lamps

CALCULATION # 1: COST OF PURCHASING FLUORESCENT LAMPS

Cost of purchasing fluorescent lamps per year*

	33,176,000	33,176,000	fluorescent tubes sold in the watershed
x	70 %	70 %	70% of the tubes sold in the watershed are 4 ft
	23,223,200	23,223,200	4 ft. fluorescent tubes sold in the watershed
x	$2	$3	Cost per 4 ft tube
Subtotal A	$46,446,400	$69,669,600	Cost of all 4 ft tubes in the watershed
	9,952,800	9,952,800	30% of the tubes sold are 8 ft
x	$3	$5	Cost per 8 ft tube
Subtotal B	$32,844,240	$46,280,520	Cost of all 8 ft tubes in the watershed
	1,885,000	1,885,000	HID lamps sold in the watershed
x	$20	$420	Cost per HID lamp
Subtotal C	$37,700,000	$791,700,000	Cost of all HID lamps in the watershed
	3,016,000	3,016,000	Compact fluorescent lamps
x	$12	$20	Cost per compact fluorescent lamp
Subtotal D	$36,192,000	$60,320,000	Cost of all compact lamps sold in the watershed
Total (A+B+C+D)	**$153,182,640**	**$967,970,120**	Costs for purchasing all fluorescent lamps in the watershed/yr

ENERGY COST SAVINGS FROM PURCHASING FLUORESCENT LAMPS INSTEAD OF INCANDESCENT BULBS, PER YEAR (250 DAYS)[1]

Flourescent Lamps								Incandescent Lamps					
Type of lamp	Average Wattage		KW/hr		KW/yr		Energy cost per year ($0.12 perKW)	KW/hr		KW/yr		Energy cost per year ($0.12 perKW)	Net savings per year
4-ft tube	40	x	928,928	x	1,857,856,000	=	$222,942,720	2,786,784	x	5,573,568,000	=	$668,828,160	$445,885,440
8-ft tube	96	x	955,469	x	1,910,937,600	=	$229,312,512	2,866,406	x	5,732,812,800	=	$687,937,536	$458,625,024
HID	75	x	141,375	x	282,750,000	=	$33,930,000	424,125	x	848,250,000	=	$101,790,000	$67,860,000
compact lamp	25	x	75,400	x	150,800,000	=	$18,096,000	226,200	x	452,400,000	=	$54,288,000	$36,192,000
Total							**$504,281,232**					**$1,512,843,696**	**$1,008,562,464**

CALCULATION # 2: RECYCLING COSTS

Cost of recycling all spent lamps[2]

Type of lamp	# in region		Cost per unit		Cost per year
4-ft tube	23,223,200	x	$0.4	=	$9,289,280
8-ft tube	9,952,800	x	$0.8	=	$7,962,240
HID	1,885,000	x	$2.5	=	$4,712,500
compact	3,016,000	x	$0.8	=	$2,262,000
Total	**38,077,000**		Total		**$24,226,020**

NOTES

* See calculation on fluorescent lamps usage in appendix 6.2 for number of fluorescent lamps sold in the watershed region

1. Martha Bell, Association for Energy Affordability, NYC, pers. communication, October 2001
2. Brian Jantzen, Full Circle, NY; personal communication, October 2001

Hospitals — *Costs/Net Savings*

SUMMARY

Cost range for using mercury products/region

	Cost range		per	Range Cost subsequent year		kg of Mercury per year	Cost range/ Kg Hg/yr (for first five years)	
thermometers	$3,485,000	$39,130,000	Year			6	$580,833	$6,521,667
sphygmomanometer	$2,113,100	$25,980,600	Year			356	$5,936	$72,979
dental cost:								
1) amalgam material only	$50,400	$75,098	Year			60	$840	$1,252
2) recycling all solid waste amalgam	$67,200	$91,350	Year			45	$1,493	$2,030
3.a) operating filtration system, or	$108,652	$225,419	/yr for 5 yrs	$79,800	$165,300	15	$7,243	$15,028
3.b) filtration service	$231,000	$261,000	/yr after 1st yr	$168,000	$217,500	15	$11,200	$14,500
laboratories (cost of alternatives for avoiding releases)								
a) filters@end of clinical analyzers	$812,681	$8,126,808	/yr for 5 yrs	$261,000	$2,610,000	620	$1,311	$13,108
b. filtration System at end of pipe	$2,323,515	$33,969,144	/yr for 5 yrs	$348,000	1,044,000	620	$3,748	$54,789
c. recapturing solutions & recycling	$7,118,182	$213,545,455	Year			620	$11,481	$344,428
d. recapturing solutions &treatment	$1,977,273	$59,318,182	Year			620	$3,189	$95,674
Cost range for using non-Hg products/region								
thermometers	$994,345	$2,859,069	per yr/ 5 yrs	$634,667	$1,926,400	60	$16,572	$47,651
sphygmomanometer	$3,161,433	$6,135,070	/yr for 5 yrs only			7700	$411	$797
dental								
1) composite materials	$231,840	$332,166	Year			60	$3,864	$5,536
2) recycling removed amalgam	$67,200	$91,350	Year			23	$2,987	$4,060
3) filter system for removed amalgam	$108,652	$225,419	per yr/ 5 yrs	$79,800	$165,300	8	$14,487	$30,056
Laboratories	N/A	N/A						

CALCULATION # 1: THERMOMETERS

COST OF USING MERCURY THERMOMETERS[1]

Mercury Thermometers

Equipment cost	Range		
	85,000	86,000	total units purchased in watershed per year[2]
x	$1	$5	cost range per unit
subtotal A	$85,000	$430,000	Cost of all mercury thermometers purchased per year by hospitals/region
Cost to clean broken units[4]			
	85,000	86,000	total units purchased in watershed per year[2]
x	10%	15%	broken units/yr. (10% of a total units)[3]
	8,500	12,900	spills per year, range
x	$400	$3,000	cost range for cleaning each spill[4]
subtotal B	$3,400,000	$38,700,000	cost range for cleaning all spills in the region
Total	$3,485,000	$39,130,000	Total annual cost associated with the use of mercury thermometers

COST OF USING NON-MERCURY THERMOMETERS:

Non-Hg Digital thermometers[5]

Equipment cost

	Range		
	85,000	86,000	beds in hospitals of the watershed[2]
/	12	12	(1 per every 12 beds)
	7,083	7,167	units required to replace mercury thermometers
x	$200	$250	cost per unit[5]
subtotal A	$1,416,667	$1,791,667	Total cost to purchase non-Hg digital thermometers
or	$345,512	$452,214	per year for 5 yrs assuming 7% interest and a constant total payment financing plan

Operating costs per year:

Plastic sleeves:

	85,000	86,000	beds in hospitals of the watershed[2]
x	2	3	temperature readings per bed per day[6]
	170,000	258,000	temperature readings for all beds per day
x	365	365	days/yr
	62,050,000	94,170,000	temperature readings per year
x	$0.01	$0.02	per plastic sleeve when purchased in bulk[5]
subtotal b.1	$620,500	$1,883,400	cost for plastic sleeves for digital thermometers per year

Total cost of using digital thermometers	Range	
Per yr for 5 yrs	$994,345	$2,378,614
per year after	$648,833	$1,926,400
Net savings for substitution w/ digital units	Range	
Per yr for 5 yrs	$2,490,655	$36,751,386
per year after	$2,836,167	$37,203,600

Batteries:

	7,083	7,167	units required to replace mercury thermometers
+	2	2	lithium batteries per yr/unit (each lasting 100 readings)
	14,167	14,333	lithium batteries required per year
x	$2	$3	cost per battery[5]
subtotal b.2	$28,333	$43,000	cost for all batteries used in digital thermometers in region per year
Subtotal B	$648,833	$1,926,400	total operating cost/year
Total (A+B)	**$994,345**	**$2,378,614**	total cost for thermometers & operating cost/yr for first 5 yrs (w/loan)
or	$648,833	$1,926,400	total cost for operating thermometers /yr after 5 yrs.

Electronic thermometers[5]

Equipment

	Range		
	7,083	7,167	units required to replace mercury thermometers
x	$400	$550	cost range per unit[5]
subtotal A	2,833,333	3,941,667	cost range to replace all units
or	$691,024	$961,336	annual cost for 5 yrs w/financial plan (7% interest)

Total cost of using electric thermometers	Range	
Per yr for 5 yrs	$1,325,691	$2,859,069
per year after	$634,667	$1,897,733
Net savings for substitution w/ digital units	Range	
Per yr for 5 yrs	$2,159,309	$36,270,931
per year after	$2,765,333	$37,232,267

Operating costs

	$620,500	$1,883,400	plastic sleeves (each @$0.01 or $0.02/bulk order),[5] assuming three readings per bed/day[6]
+	$14,167	$14,333	1 battery/yr/unit @$2 each (2 required, lasting 2 years at 100 readings per day)
subtotal B	$634,667	$1,897,733	total operating cost/year (see calculation for digital thermometers, above)
Total (A+B)	**$1,325,691**	**$2,859,069**	total cost/using electronic thermometers/yr for first 5 yrs.
or	$634,667	$1,897,733	total cost/using electronic thermometers/yr after 5 yrs.

CALCULATION # 2: SPHYGMOMANOMETERS

COST OF USING MERCURY SPHYGMOMANOMETERS

Equipment Costs

Mobile units		Range	
	85,000	86,000	total units used in watershed region (average of 1 per bed)[7]
x	10%	15	% are mobile units[7]
	8,500	12,900	mobile units in hospitals of the watershed
x	10%	20	% units may be broken per year[7]
	850	2,580	mobile units replaced per year (range)
x	$250	$350	cost range per mobile unit[5]
Subtotal a.1	$212,500	$903,000	Cost range of all Hg mobile units purchased/yr by hospitals/region

Wall-mounted Units		Range	
	85,000	86,000	total units used in watershed region (average of 1 per bed)[7]
x	85%	90	% are wall-mounted units[7]
	72,250	77,400	wall-mounted units in hospitals of the watershed region
x	4%	7	% units may be broken per year[7]
	2,890	5,418	wall-mounted units replaced per year
x	$140	$200	cost range per wall-mounted unit[5]
subtotal a.2	$404,600	$1,083,600	Cost range of purchasing Hg wall-mounted units/yr by hospitals/region
Subtotal A	$617,100	$1,986,600	Total cost range of purchasing Hg sphygmomanometers/yr in region

Cost of cleaning mercury spills associated with broken sphygmomanometers:

		Range	
	850	2,580	spills due to broken wall-mounted units
x	2,890	5,418	spills due to broken mobile units
	3,740	7,998	total number of spills per year in the region (range)
x	$400	$3,000	cost range per mercury spill clean-up[4]
Subtotal B	$1,496,000	$23,994,000	total cost for cleaning mercury spills per year in all hospitals
Total(A+B)	**$2,113,100**	**$25,980,600**	total cost/yr for using mercury sphygmomanometers/yr by all hospitals in region

COST OF REPLACING ALL MERCURY UNITS WITH NON-MERCURY SPHYGMOMANOMETERS[8]

		Range	
	8500	8500	mobile units in all hospitals of the watershed
x	$250	$450	cost range per unit
subtotal A	$2,125,000	$3,825,000	cost range to replace all mobile units in all hospitals
	72,250	72,250	wall-mounted units in all hospitals of the watershed
x	$150	$250	cost range per unit
subtotal B	$10,837,500	$18,062,500	cost range to replace all wall-mounted units in hospitals of the watershed
Total (A+B)	**$12,962,500**	**$21,887,500**	Total cost range to replace all existing mercury sphygs. in watershed
or	$3,161,433	$6,135,070	per year for 5 years assuming 7% interest and a constant total payment financing plan

No additional costs after five years

Cost range to replace all units/region	
$3,161,433	$6,135,070
No additional cost after five years	
Net Savings range from substitution	
-$1,048,333	$19,845,530

Dental Services in Hospitals

CALCULATION # 1: COST OF USING MERCURY

COST OF USING MERCURY AMALGAM[9]

	Range		
	140	145	dental clinics in hospitals of the watershed region
x	960	1,200	amalgams per hospital per year[10]
	134,400	174,000	restorations per year for all hospitals
x	75%	83%	are mercury amalgam
	100,800	144,420	mercury amalgams per year for all hospitals
x	$0.50	$0.52	average cost range of materials/amalgam
Subtotal A	50,400	75,098	cost of mercury amalgam material only, for all hospital clinics/region

RECYCLING COST OF SOLID WASTE CONTAINING MERCURY AMALGAM[11]

	$40	$45	per container of mercury sent for recycling
x	10	14	containers shipped to recycler per year per dental clinic
	$480	$630	cost to recycle solid waste amalgam per dental clinic
x	140	145	hospitals offering dental services in region
Subtotal B	$67,200	$91,350	cost to recycle solid waste amalgam by all dental clinics in region
Total (A+B)	**$117,600**	**$166,448**	total cost range associated with using mercury amalgam by all clinics in the watershed

CALCULATION # 2: CONTINUE TO USE HG AMALGAM WHILE INSTALLING & MANAGING FILTERING SYSTEM[12]

Equipment cost (one-time)

	Range		
	$695	$1,400	Equipment fee (one unit serves 6 dental chairs)[12]
+	$150	$300	Installation of separator filter system (one-time)
	$845	$1,700	cost of equipment installed per hospital's dental clinic
x	140	145	dental clinics in hospitals of the watershed region
Subtotal A	$118,300	$246,500	cost of equipment installed for all dental clinics in hospitals in region
or	$28,852	$60,119	cost of equipment at all clinics/yr. assuming a 5yr loan (7% interest w/constant payment plan)

Operating expenses per year

	$150	$150	cost for filter cartridges
x	3	6	filters changed per year
	$450	$900	cost range for filter cartridges per clinic
+	$120	$240	cost associated with recycling filters (3-6T/yr @$40 ea.T)
	$570	$1,140	cost installing & operating filter per clinic
x	140	145	dental clinics in hospitals of the watershed region
Subtotal B	$79,800	$165,300	cost for operating filter/yr for all dental clinics in hospitals in the region
Total: A+B	**$108,652**	**$225,419**	cost for first 5 yr of installing & operating filter/yr for all dental clinics in hospitals (with loan)
	$79,800	$165,300	cost for operating filter/yr after 5 yrs. for all dental clinics in hospitals in the region

CALCULATION # 3: CONTINUE TO USE HG AMALGAM WHILE CONTRACTING FOR A SERVICE TO INSTALL & MANAGE FILTERING SYSTEM

First year

	Range		
	$150	$300	Installation of separator filter system. Equipment fee is waived[12]
+	$1,200	$1,500	Cost of full service/yr (replacement & disposal of filters)[12]
	$1,650	$1,800	Total cost of using filter system service for first year per hospital dental clinic
x	140	145	dental clinics in hospitals of the watershed
	$231,000	**$261,000**	Total cost of using filter system service for first year, all hospital dental clinics in region

Each subsequent year

	$1,200	$1,500	Cost of full service per year (replacement & disposal of filters)
x	140	145	dental clinics in hospitals of the watershed
	$168,000	**$217,500**	Total cost per year after initial yr./ all dentists in watershed

CALCULATION # 4: COST OF MATERIAL SUBSTITUTION

Use of Composite materials

	Range		
	100,800	144,420	new restorations per year at all hospital dental clinics in the watershed (see previous page)
x	$2.3	$2.3	cost of composite material only, per unit[13]
Subtotal A	**$231,840**	**$332,166**	cost of composite material for all new restorations/yr
Subtotal B	$67,200	$91,350	Total cost of recycling 100% of removed amalgams disposed as solid waste
Subtotal C	$108,652	$225,419	Total cost for filter system to trap old amalgam removed (1st 5yrs assuming loan)
or	$79,800	$165,300	Total cost of installing and operating filter system (per year afterwards)
Total (A+B+C)	**$407,692**	**$648,935**	Total cost of substituting for composite materials (per yr/for first 5 yrs, assuming loan)
	$378,840	$588,816	Total cost associated with substituting for composite materials (per yr after 5 yrs)

Laboratories in Hospitals

CALCULATION # 1

EFFLUENT MANAGEMENT FILTRATIONS SYSTEM AT END OF CLINICAL ANALYZERS

Equipment cost

	Range		
	$5,000	$50,000	cost of 1 to 10 wastewater filter system(s) each serving 3 clinical analyzers[15]
+	$200	$2,000	Installation fee of wastewater filter(s)
	$5,200	$52,000	cost range of installing filtration system at each hospital laboratory
x	435	435	laboratories in hospitals of the watershed[14]
Subtotal A	$2,262,000	$22,620,000	total cost range of equipment installed at hospital
or	$551,681	$5,516,808	Sub-total w/amortization (7% interest, 5 years)

Operating cost

	$600	$6,000	Filter replacement & disposal/yr/lab ($150ea.x 4T/yr)
	435	435	hospital labs in watershed[14]
Subtotal B	$261,000	$2,610,000	total operating cost of filtration system for all hospital laboratories in region
Total (A+B)	**$812,681**	**$8,126,808**	Total Cost/yr for first 5 yrs for filtration systems at all hospital laboratories in region
	$261,000	$2,610,000	Total cost of operating filtration systems per year after 5 yrs.

CALCULATION # 2

EFFLUENT MANAGEMENT AT END OF PIPE

Filtration System at end of pipe-

	Range		
	$30,000	$500,000	cost range for filtration system per laboratory (1/ lab -cost varies by volume discharged)
x	435	435	hospital labs in watershed[14]
Subtotal A	$13,050,000	$217,500,000	cost range of equipment for all hospital laboratories in the region
or	$1,975,515	$32,925,144	Cost range per year for 5 years assuming loan (7% interest, 5 years)

Operating cost

	$800	$2,400	Filter replacement & disposal/yr/lab ($200ea.filter changed min. of 4T/yr.)
x	435	435	hospital labs in watershed[14]
Subtotal B	$348,000	$1,044,000	cost per year of operating filtration system by all labs in region
Total (A+B)	**$2,323,515**	**$33,969,144**	Total cost per yr/for first 5 yrs for filtration system at all labs in region, (assuming loan)
	$348,000	$1,044,000	Total cost per year after 5 yrs. for operating filtration system by all labs in region

CALCULATION # 3

RECAPTURING ALL DISCHARGES

Recapturing all discharges plus recycling

	Range		
	1	30	analyzers per laboratory
x	500	600	gallons per analyzer per yr[16]
	500	15,000	gallons per lab /yr (range)
/	55	55	gallons per drum of recaptured solutions[17]
	9	273	number of 55 gallon-drums/lab/yr
x	$1,800	$1,800	cost to recycle each drum of recaptured solutions[17]
	$16,364	$490,909	cost to recycle all recaptured solutions per lab per year
x	435	435	laboratories in hospitals in the watershed[14]
	$7,118,182	**$213,545,455**	Cost per yr to recycle all recaptured solutions by all hospital laboratories in the region

Recapturing all discharges and sending them for treatment for disposal at landfills

	1	30	analyzers per laboratory
x	500	600	gallons per analyzer per yr[16]
	500	15,000	gallons per lab /yr (range)
/	55	55	gallons per drum of recaptured solutions[17]
	9	273	number of 55 gallon-drums/lab/yr
x	$500	$500	cost for treatment of each drum of recaptured solutions[17]
	$4,545	$136,364	cost for treatment of all recaptured solutions per lab per year
x	435	435	laboratories in hospitals in the watershed[14]
	$1,977,273	**$59,318,182**	Cost per yr for treatment of all recaptured solutions by all hospital laboratories in the region

NOTES

1. MERC- Pollution Probe, November 1996.
2. See note #2, Hospital Mercury Usage
3. MERC- Pollution Probe, November 1996.
4. The total cost of cleaning may be just as low as the price of a spill kit. However, hidden costs include disposal rates, special equipment and clothing used during proper removal, personnel training and wages, loss of service if room is temporarily closed. Cost can be as high as $3,000 if carpet needs to be replaced and old carpet sent to retorter facility. Personal communication with Marvin Stillman, May 4, 2001. Also see MERC- Pollution Probe, November 1996.
5. Welch Allyn Medical Catalogue 2001 (price for Sure-temp #1679-200 - oral/rectal) and MERC - Pollution Probe, November 1996.
6. Personal communication with Marvin Stillman (see Appendix 6.2)
7. See note # 4 on Hospitals -Mercury usage page. Mobile units break at a higher rate than wall mounted units.
8. Welch Allyn Medical Catalogue 2001, and MERC- Pollution Probe, November 1996
9. Prices for mercury capsules (Henry Schein Alloys) are for purchases in bulk. Prices for the (Charisma Heraeus Kulser) resin composite for both anterior and posterior restorations are based on syringe refills. All prices are reported on http://www.sullivanschein.com and are similar to other dental catalogues (Dentsply-Caulk and Kerr).
10. See Dental services in page describing hospital uses, Appendix 6.2
11. Assumes hg shipped to retorting facility directly by common carrier at a cost of $40 per up to 30 lbs, each time. NY and NJ accept the RCRA, RECRA code for mercury permitting such shipments. Does not include wastewater filter system.
12. Information from SolmeteX Co. and DRNA Co. See Dental Sector Section for detailed information.
13. http://www.sullivanschein.com; Charisma Heraeus Kulser; Dentsply-Caulk and Kerr catalogues.
14. http://www.hospitalselect.com and CenStats (1997SIC Comparison) Zip Code Business Patterns at http://tier2.census.gov/cgi-win/zbp/compares.exe Each hospital may have more than one laboratory.
15. Each laboratory may have between 1 to 30 clinical analyzers which discharge mercury and other chemicals directly to sewage system. Options available: a) the Effluent Management System (EMS) attached directly to the clinical analyzer(s) which cost about $5,000 per filter system serving 3 analyzers each. Cartridge per EMS replacement costs $150 each time and needs to be changed every 3 months ; or b) End of pipe systems that costs between $30,000 to $500,000 depending on volume (larger system can filter up to 100,000 gallons/sec) Filter cartridges cost $200. Pers.comm. with Owen Boyd, SolmeteX
16. Calculation by Gregory Camacho, Industrial Hygienist, NY Presbyterian Hospital of Cornell and Columbia Universities. Pers. comm. October 2001.
17. Clean Harbors Environmental Services; Pete and Shana Wilson, personal communication, October 2001.

Laboratories (excluding hospitals) — *Costs/Net Savings*

SUMMARY

Range			kg Hg released /yr	Cost/Kg Hg released/yr	
Filtration System at end of clinical analyzers*					
$1,566,000	$15,660,000	cost/yr for first 5 yrs.	400 kg to wastewater	$3,915	$39,150
$162,000	$1,620,000	cost/ yr afterwards	400 kg to wastewater	$405	$4,050
Filtration System at end of pipe					
$2,191,515	$33,573,244	cost/yr for first 5 yrs.	400 kg to wastewater	$5,479	$83,933
$216,000	$648,000	cost/ yr afterwards	400 kg to wastewater	$540	$1,620
Recapture solutions & recycle them					
$4,418,182	$132,545,455	cost per year	400 kg to wastewater	$11,045	$331,364
Recapture solutions, treat & send them to landfills					
$1,227,273	$36,818,182	cost per year	400 kg to wastewater	$3,068	$92,045

CALCULATION # 1

EFFLUENT MANAGEMENT FILTRATION SYSTEM AT END OF CLINICAL ANALYZERS*

Equipment cost

	Range		
	$5,000	$50,000	cost of 1-10 filter system(s) ea. serving 3 clinical analyzers. Each lab w/up to 30 analyzers[1]
+	$200	$2,000	Installation fee of wastewater filter(s)[2]
	$5,200	$52,000	cost range of installing filtration system at each laboratory
x	270	270	laboratories in the watershed region[3]
Subtotal A	$1,404,000	$14,040,000	total cost range of equipment installed at laboratories in region
or	$342,423	$3,424,225	Sub-total w/loan (7% interest, 5 years)

Operating cost

	$600	$6,000	Filter replacement & disposal/yr/lab ($150 ea.x 4T/yr)
	270	270	labs in watershed[3]
Subtotal B	$162,000	$1,620,000	total operating cost of filtration system for all laboratories in region
Total (A+B)	**$1,566,000**	**$15,660,000**	Cost/yr/first 5 yrs for installing & operating filtration systems at all hospital labs/region
	$162,000	$1,620,000	Cost of operating filtration systems per year after 5 yrs.

CALCULATION # 2

END OF PIPE FILTRATION

	Range		
	$30,000	$500,000	cost range of installing filtration system/lab (1/lab -cost varies by volume discharged)[2]
x	270	270	labs in watershed region[3]
Subtotal A	$8,100,000	$135,000,000	cost range of equipment for all laboratories in the region
or	$1,975,515	$32,925,244	Cost range per year for 5 years assuming loan (7% interest, 5 years)

Operating cost

	$800	$2,400	Filter replacement & disposal/yr/lab ($200ea.filter changed min. of 4T/yr.)
x	270	270	labs in watershed region[3]
Subtotal B	$216,000	$648,000	Cost per year of operating filtration system by all labs in region
Total (A+B)	**$2,191,515**	**$33,573,244**	Cost per yr/for first 5 yrs for installing & operating filtration system at all labs in region
	$216,000	$648,000	Cost per year after 5 yrs. for operating filtration system by all labs in region

CALCULATION # 3

RECAPTURING ALL DISCHARGES, PLUS RECYCLING OR TREATMENT

A. Recapturing all discharges to recycle them[4]

	Range		
	1	30	analyzers per laboratory
x	500	600	gallons per analyzer per yr[5]
	500	15,000	gallons per lab /yr
/	55	55	gallons per drum of recaptured solutions[4]
	9	273	number of 55 gallon-drums/lab/yr
x	$1,800	$1,800	cost to recycle each drum of recaptured solutions[4]
	$16,364	$490,909	cost to recycle all recaptured solutions per lab per year
	270	270	laboratories in the watershed region[3]
	$4,418,182	**$132,545,455**	Total Cost per yr to recycle all recaptured solutions by all laboratories in the region

B. Recapturing all discharges and sending them for treatment for disposal at landfills[4]

	1	30	analyzers per laboratory[1]
x	500	600	gallons per analyzer per yr[5]
	500	15,000	gallons per lab /yr
/	55	55	gallons per drum of recaptured solutions[4]
	9	273	number of 55 gallon-drums/lab/yr
x	$500	$500	cost for treatment of each drum of recaptured[4]
	$4,545	$136,364	cost for treatment of all recaptured solutions per lab per year
	270	270	laboratories in the watershed region[3]
	$1,227,273	**$36,818,182**	Total Cost per yr for treatment of all recaptured solutions by laboratories in region

NOTES

*Each system can serve 3 clinical analyzers

1. Each laboratory may have between 1 to 30 clinical analyzers which discharge mercury and other chemicals directly to sewage system. Options available: a) the Effluent Management System (EMS) attached directly to the clinical analyzer(s) which cost about $5,000 per filter system serving 3 analyzers each. Cartridge per EMS replacement costs $150 each time and needs to be changed every 3 months ; or b) End of pipe systems that costs between $30,000 to $500,000 depending on volume (larger system can filter up to 100,000 gallons/sec) Filter cartridges cost $200. Pers.comm. with Owen Boyd, SolmeteX
2. Owen Boyd, SolmeteX Co., MA; pers. Communication, June 2001
3. http://www.hospitalselect.com and CenStats (1997SIC Comparison) Zip Code Business Patterns at http://tier2.census.gov/cgi-win/zbp/compares.exe Each hospital may have more than one laboratory.
4. Clean Harbors Environmental Services; Pete and Shana Wilson, personal communication, October 2001.
5. Calculation by Gregory Camacho, Industrial Hygienist, NY Presbyterian Hospital of Cornell and Columbia Universities. Pers. comm. October 2001. Each clinical analyzer uses 27 new containers of reagents on a daily basis. Each container carries about 300 ml.

SUMMARY

Cost range to manage mercury switches:			kg of Hg	Cost range per kg managed	
$456,584	$603,820	Removal of switches at end-of-life of vehicle	900	$507	$671
$8,774,158	$13,380,679	Replacement of switches from entire car fleet in region	9700	$905	$1,379
-$40,000	see note # 9	Substitution of mercury switches by manufacturer	N/A	N/A	

CALCULATION # 1

Removal of Switches at end-of life of vehicles

Centralized operation (before vehicle is compacted)

> Cost per year to remove switches from vehicles at end-of-life in the watershed
> Range
> **$446,684 $603,820**

Equipment cost

	900	kg of mercury in switches disposed per year
x	2.2	lbs in a kilogram
	1,980	lbs of mercury in switches disposed of yearly[1]
/	10	lbs of mercury per 30 lb container of switches[2]
	198	containers needed per year to recover all switches disposed in the watershed region
x	$50	per container sent by common carrier[3]
Sub-total A	$9,900	Sub-total: cost of containers sent directly to Hg recycling/retorting facility

Labor costs

	Range		
	744,474	1,113,600	range of automotive mercury switches disposed in watershed per year[4]
/	20	30	mercury switches removed per hour[5]
	37,224	37,120	hours required to removed all mercury switches disposed per year
x	$12	$16	labor costs per hour (including overhead) to remove 30 switches[5]
Sub-total B	$446,684	$593,920	Sub-total: labor cost to remove switches
TOTAL (A + B)	**$456,584**	**$603,820**	Total cost range to remove mercury switches for end-of-life vehicles in the watershed

Replacement of all mercury switches in all cars in the watershed

> Cost range to replace all Hg switches from all vehicles in the watershed
> **$8,774,158 $13,380,679**

Cost of replacement switches (ball bearing type)

	7,444,740	7,444,740	vehicles in the watershed[6]
x	1	1.6	mercury switches per vehicle[6]
	7,444,740	11,911,584	mercury switches in vehicles of the watershed
x	$0.35	$0.45	per replacement (non-mercury switch)[7]
Sub-total A	$2,605,659	$5,360,213	cost range of replacement switches for all cars

Labor cost

	7,444,740	11,911,584	mercury switches in vehicles in the watershed area
/	15	$25	switches replaced per hour[8]
	496,316	476,463	hours required to replace all mercury switches
x	$12	$16	labor cost per hour (including overhead)[5]
Sub-total B	$5,955,792	$7,623,414	labor cost range to replace all mercury switches

Recycling cost for Hg switches replaced

	7,444,740	11,911,584	mercury switches in vehicles of the watershed
/	420	$450	mercury switches per container (3 lbs of switches with 1 lb of mercury)[8]
	17,726	26,470	containers required to replace all mercury switches in all vehicles in watershed region
x	$12	$15	per 3 lbs container sent by common carrier[8]
Sub-total C	$212,707	397,053	Sub-total: cost of containers sent directly to Hg recycling/retorting facility
Total (A+B+C)	**$8,774,158**	**$13,380,679**	cost range to replace all automotive Hg switches in the watershed (stock as of 1998)

NOTES

1. Appendix 6.2 under *Automotive switches/releases*
2. http://www.epa.gov/region5/air/mercury/autoswitch.htm
3. Sent by common carrier directly to recycler or retorting facility, in a hermetically sealed refrigerator-type-box which fits tightly inside a cardboard box. Both NY and NJ accept the RCRA rule to allow container shipments of 30 lbs or less by common carrier.
4. Appendix 6.2 under *Automotive switches/releases*.
5. For amount of mercury switches that can be removed per hour and cost of removal go to http://www.epa.gov/region5/air/mercury/autoswitch.htm#remove
6. From Appendix 6.2 under Automotive Switches /Mercury Usage.
7. NY S Department of Conservation's Mercury Reduction Program (January, 2001); Toxics in Vehicles: Mercury. This document indicates that the cost of replacement switches is $0.38 per switch and installment takes less than one minute. (Replacement is solid copper switch that is silver plated, single ball bearing inside a tilt switch).
8. Tom Corbett (NYS DEC, Mercury Reduction Program); personal communication, October 10, 2001
9. EPA, Office of Air Quality Planning & Standards and Office of Research and Development (1997); Mercury Study Report to Congress; Chapter VIII, page 5-9 indicates that Chrysler Co. estimated it would save about $40,000 using rolling ball switches instead of a mercury switches. Savings would accrue mostly from avoided liabilities and risk involved in managing hazardous materials during manufacturing. Called Ana Smith and Kathy Gran at Daimler-Chrysler to inquire number of cars involved in calculation, but information was not available at the time of this report.

Households: Thermometers *Cost/Net Savings*

SUMMARY

Cost Range of Mercury thermometers sold in the watershed/yr		kg of Hg released/yr	Cost/kg	
$1,547,000	**$2,587,000**	500	$3,094	$5,174

Cost of replacing them with digital thermometers		kg of Hg released/yr	Cost/kg	
$3,237,000	**$5,187,000**	500	$6,474	$10,374

CALCULATION # 1

Cost of Mercury thermometers sold in the watershed per year

	Range		
	1,300,000	1,400,000	Units sold/yr[1]
x	$1.19	$1.99	Unit cost range[2]
	$1,547,000	**$2,587,000**	Cost range for watershed region

Cost of replacing them with digital thermometers

Range		
1,300,000	1,400,000	Units sold/yr[1]
$2.49	$3.99	Unit cost range[2]
$3,237,000	**$5,187,000**	Cost range for watershed region

NOTES

1. For thermometers sold in the watershed region per year, see calculation in Appendix 6.2/Thermometers/Mercury Usage.
2. Welch Allyn Medical Products catalogue

Thermostats — *Costs/Net Savings*

SUMMARY

Cost range of using mercury thermostats including 100% recycling		kg of Hg released/yr	Cost/kg	
$7,084,286	**$23,664,000**	600	$11,807	$39,440

Costs of purchasing non-Hg digital thermostats		kg of Hg released/yr	Cost/kg	
$11,597,100	**$111,360,000**	600	$19,329	$185,600

CALCULATION # 1

Cost of purchasing mercury thermostats

	Range		
	290,000	464,000	Range of units sold in the watershed region per year[1]
x	$24	$80	Cost range of mercury thermostats[2]
Sub-total A	$6,960,000	$23,200,000	Cost of purchasing new mercury thermostats per year in the watershed region

Cost of comprehensive recycling

	Range		
	290,000	464,000	units sold /yr replacing old ones
/	35	45	units per container[3]
	8,286	10,311	containers required for comprehensive recycling per year
x	$15	$45	per container, by TRC ($15), or by common carrier, cost per time sent to recycler[3]
Sub-total B	$124,286	$464,000	cost range of comprehensive recycling
Total (A+B)	**$7,084,286**	**$23,664,000**	range of total cost associated with the use of mercury thermostats

Cost of substitution (non-mercury thermostats)

	Range		
	290,000	464,000	Range of units sold in the watershed region per year[1]
x	$40	$240	Cost range of non-mercury thermostats[2]
	$11,597,100	**$111,360,000**	Cost of purchasing new non-mercury thermostats per year in the watershed region

NOTES

1. For units sold in the region, see calculation in Appendix 6.2
2. http://content.honeywell.com/yourhome/ptc-thermostats/Therm_Choose.htm and price confirmation by phone 800.345.6770x7409. Also Thurman Industries, www.paynpak.com, 425.259.2538.
3. Thermostat Recycling Corporation (TRC) (1999); *Wholesaler Questions and Answers to the Mercury Thermostat Recycling Program* http://www.nema.org/government/environmental